# COMBUSTION

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Central Arizona Light and Power Company, Phoenix, Arizona

## FUEL PERFORMANCE CALCULATIONS

By P. B. Place

## CENTRAL ARIZONA HAS UNUSUAL CONSTRUCTION FEATURES

By W. F. Friend and E. H. Krieg

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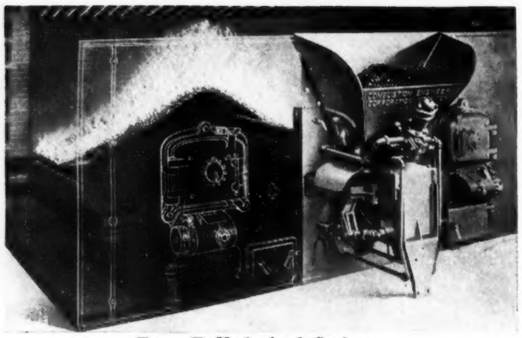
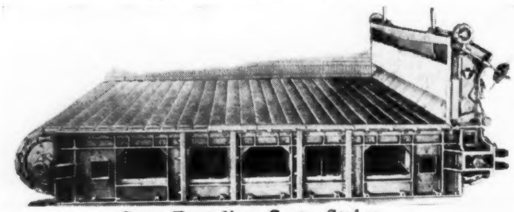
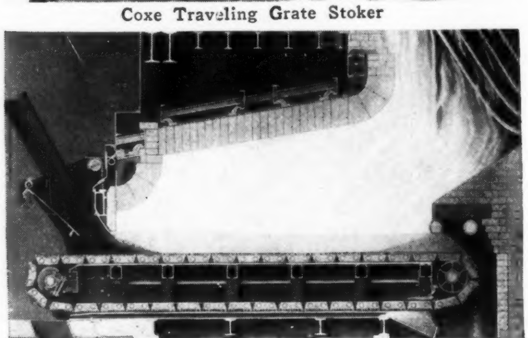
JOSEPH KEENAN • GEORGE RAMSEY • DAVID BROWNLIE



Type E Underfeed Stoker

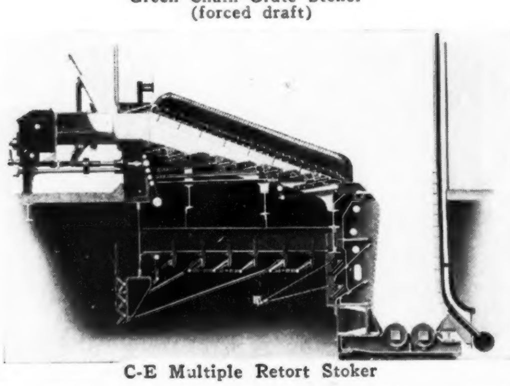


Coxe Traveling Grate Stoker

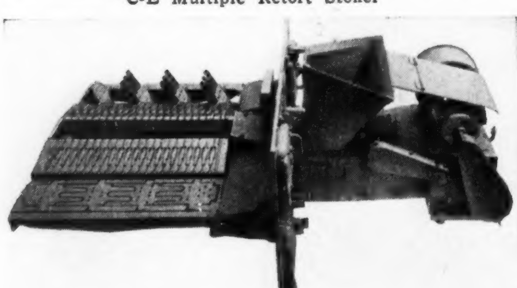


Green Chain Grate Stoker
(natural draft)

Green Chain Grate Stoker
(forced draft)



C-E Multiple Retort Stoker



Type E Stoker-Unit

# STOKERS

## All Types
## All Sizes
## For All Coals

The names, Type E, Coxe and Green, today, as for many years past, are synonymous with leadership in the stoker field. Viewed from the standpoints of engineering recognition, number of stokers installed or amount of boiler surface equipped, each of these stokers dominates its class.

In addition to these three stokers, Combustion Engineering Corporation manufactures the several other types illustrated on this page. The newest member of the family is the Type E Stoker-Unit for boilers in the approximate range of 40 to 150 hp. This stoker, modeled after its famous forbear—the Type E Stoker—is introducing new standards of performance in the small stoker field. Also illustrated is the C-E Multiple Retort Stoker, six of which were recently purchased for the new Federal Government Heating Plant, the contract being the largest for stokers awarded so far this year.

**When you buy a stoker, *consider these facts:***

**—Combustion Engineering Corporation has installed over 14,000 stokers in this country alone (Several thousand more have been installed by associated companies abroad),**

**—a large percentage of its total business is made up of repeat orders.**

**—its experience embraces all conditions of operation, all kinds of coal and all types and sizes of stokers.**

You can depend upon it that any stoker sold by this organization will be of a type suitable for your fuel and operating conditions, will be built to give many years of reliable service with minimum operating and maintenance charges, will be properly erected and installed, and will meet all performance guarantees.

**COMBUSTION ENGINEERING CORPORATION**

200 MADISON AVENUE NEW YORK

# COMBUSTION

VOLUME FOUR • NUMBER FOUR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H. STUART ACHESON, *General Representative* — CHARLES McDONOUGH, *Editor* — F. H. ROSENCRANTS, *Associate Editor*

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# Commentary by Joseph H. Keenan

## Heat—The Quest of a Definition*

MOST of us, like Josh Billings, feel that "it is nice to know a lot of things, especially if some of them are so." With touching complaisance we gather knowledge from textbooks and professors quite conscious that we can never reconcile much of it with things we know to be so.

As students we found that the whole structure of thermodynamics was set upon a hurriedly inspected definition of heat which in substance ran something like this: "Heat is energy stored in a body which is evidenced by the temperature of the body, and which may be explained by the position and motion of its molecules." Where it was not stated a similar definition was usually implied, as in the case of one outstanding American text which refers to the heat which "disappears" from a substance during certain changes, indicating that heat is energy in storage which may appear or disappear as the store is added to or subtracted from.

It subsequently appeared that internal energy was also energy stored within the substance. It was quite apparent that unless heat were stored in red barrels and internal energy in blue barrels we should have trouble trotting out the right sample on examination day.

Nor did further study clear up the confusion. We soon learned that an adiabatic expansion is one in which no heat enters or leaves the expanding substance, but in many adiabatic expansions the energy stored in the substance decreases. If this is heat it has all the agility of a magician's rabbit.

It is nice to know all these things, but it would be nicer to know which of them are so. If thermodynamics can be expounded in scientific language there must be a specific and uncontradictory definition of the term heat implied in its fundamentals. Only such a definition will serve in an adequate derivation or discussion of the corollaries of the fundamentals which constitute the science.

The thermodynamics of the mechanical engineer has only two fundamental principles. The first principle restates the law of conservation of energy to the effect that if more energy is added to a substance than is removed from it during a process, then the amount of energy stored in the substance must increase. It refers to the kinds of energy that may be added or removed as work and heat. The energy in storage, which may increase or decrease, it calls internal energy.

This is unequivocal enough. Energy which has passed into storage during a process is internal energy. Heat must be something else.

The second principle of thermodynamics states in part that the maximum work which can be obtained from any heat engine is equal to the product of a temperature ratio and the *heat added* to the working substance.

If we have been looking for a description of the heat *in* a substance we have not found it. Both principles refer only to heat as it enters or leaves a substance. It appears that the science of thermodynamics has been built on a foundation in which heat is considered only as energy in transition. The energy which is called heat while it is being transferred appears after the transfer as work done or internal energy; it is no longer heat.

We have arrived at a partial definition: Heat is energy in transition. Unfortunately it violates many of our old conceptions. We cannot now say that a gallon of hot water has more heat in it than a gallon of cold water. Noah Webster says we can, but Noah was always a little weak in thermodynamics.

Perhaps we have believed that the latent heat of steam was really heat. We put it to the test and find it is not energy in transition. Then it is not heat. And so it is with specific heat, and total heat, and that bit of unresolved dissonance, heat content.

A century ago the caloric theory flourished. It claimed that "heat is an imponderable fluid incapable of being created or destroyed, which permeates the interstices of all matter." It was to portions of this fluid that the names latent heat, specific heat and heat content were applied. The imponderable fluid has been totally discredited and has slithered off into obscurity, but its vapors linger in our nomenclature.

Joseph H. Keenan

Stevens Institute of Technology

* This discussion will be continued in the next article.

# EDITORIAL

## A "Drive" That Deserves the Support of Engineers

WE seem to be living in an era of "drives". Undoubtedly they all have commendable objectives but occasionally we hear about one that seeks to remedy a condition with which we are personally familiar. Such a drive was recently announced in the daily newspapers. Its purpose is to promote equipment buying as an economically justifiable means of relieving unemployment.

The program will be carried forward by a committee under the direction of A. W. Robertson, chairman of the National Committee on Industrial Rehabilitation and chairman of the board of the Westinghouse Electric & Manufacturing Company. An organization is to be set up by the committee, which is an outgrowth of the recent conference of banking and industrial committee of the twelve Federal Reserve districts called by President Hoover, and this group will carry on the proposed campaign throughout the country.

Mr. Robertson stated that the objective of the movement was to provide work for 1,620,000 former employees of manufacturers of machinery, equipment, and plant accessories whose average normal output has dropped from over five billion to slightly more than one billion dollars annually.

As Mr. Robertson explained it, "This committee will concentrate on getting manufacturers in all the principal production centers to modernize their plants now, when their machinery is run down, when financial and credit conditions are improved and installation costs are low." Quoting him further, "The committee believes that if industry will proceed now for reasons of sound self-interest to put its house in order and to remedy through modernization the run-down condition of its productive equipment, employment will be created for hundreds of thousands of workers in the 'capital goods' industries. In addition it will bring back on pay rolls hundreds of thousands of workers in other industries which furnish the parts, raw materials and services bought by the machinery and equipment manufacturers. This will release millions of dollars in wages spent for individuals and family purchases affecting business in every community."

In other words, simply by making an investment that will quickly pay for itself at a time when the amount required is less than it is going to be for a long time to come, the equipment user will contribute to general prosperity from the creation of which he will derive still further benefit.

The logic of this idea is as compelling as it is obvious. Everybody in industry knows that equipment prices today are at bed-rock. Everybody also knows that as soon as things start to pick up there will be a demand for the replacement of worn-out, obsolete and inefficient equipment which will send prices up, make deliveries slower at a time when delay will cost money, and inject an element of haste into the situation which will militate against the best results.

Here is a drive that deserves cooperation. Those who believe that sound capital investment to create employment is a better way of improving conditions than contributions to unemployment relief should get behind this movement and give it their full support.

## The New Role of the Engineer

MUCH has been said and written in recent years relative to the changing status of the engineer and the need for recognition of this in preparatory training for his profession. No longer can the engineer be regarded as a specialist who should be left in his own sphere and who can contribute little to business outside of that sphere.

The number of engineers who have attained executive or official status in the businesses with which they are identified is already great and is increasing each year. In this fact is evidence of the growing tendency on the part of leaders of business to recognize that engineering training develops qualities of mind and a technique of thinking which admirably equips its recipients for executive responsibility.

All of which makes apparent the importance of introducing into engineering curricula a more liberal allotment of economics and other courses which will equip the engineer for the more important role he is to play in the business structure of the future. Time for such courses can be found by revising curricula so as to place major emphasis on principle and considerably less on methods. Education would do well to ponder upon the simple yet wise theory of ancient Chinese pedagogy which taught that the solution of difficult problems becomes easy when the underlying principles are understood.

One of the many encouraging signs in this direction is the recent occurrence of The Second Annual Economic Conference for Engineers, held at Stevens Engineering Camp, August 7 to September 5. This meeting, sponsored by the Alumni societies of the leading technical schools and universities and by the American Association for Adult Education, was devoted to the general theme of money and banking. During the nine-day session, notable authorities presented papers on the fundamentals of these important subjects considered especially in the light of development during the past three years.

# Patents*

By GEORGE RAMSEY
NEW YORK
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Member A. S. M. E.

## PART III

**What happens to an application for patent after it reaches the Patent Office? How should the application be prepared to meet the requirements of Patent Law and of the "Rules of Practice" of the Patent Office? What is the function of claims, and what general rules should be observed in their preparation in order to avoid objection or rejection by the Examiner and at the same time afford the maximum strength and protection to the patent? These are some of the questions which the author discusses in this, the third article in his series. The all important subject of claims will receive further consideration in subsequent articles.**

### Patent Office Procedure

The application for patent having reached the Patent Office, it is mounted in a heavy jacket furnished by the Patent Office, namely, the "file wrapper". These jackets are of uniform shape to fit applications for patents, which the Rules require shall be on legal size paper. On the front of the jacket is noted the name and address of the inventor; the name of the assignee and the amount of the interest assigned, if there is an assignee of record; the serial number of the application; title of the invention; and date upon which the complete application was received in the Patent Office; and the name and the address of the attorney. On the back of the jacket are numbered lines on which are to be recorded the contents of the file wrapper; that is, a notation of each rejection and amendment is to be entered on the jacket on the date when sent out or received.

The jacketed application is sent to the Division examining the subject-matter of the application. The clerk in the Division enters the application in the Division docket book in which is kept the entire history of the case from the time it comes into the Division until it leaves, by transfer, or as a patented file, or as an abandoned application. Having docketed the application, the clerk refers it to the Assistant Examiner who is assigned to examine cases to which the one in question belongs. Most of the examining work is done by the Assistant Examiners. The Principal Examiner supervises the work of the Assistants and in most cases, goes over each examination with the Assistant before the Official letter or action is written.



### *Examination*

The new application takes its place in chronological order with the other new applications on the Examiner's desk and is reached for examination in regular order in due time. When examining a case, the Examiner usually looks first at the drawings (drawings accompany nearly all mechanical cases, but not usually chemical cases) to get a general concept of the invention. He then carefully reads the specification with the drawings in front of him and he locates on the drawings the parts designated by common reference numerals on the drawings and in the specification. As he reads along he may note such errors as he finds. Having read the specification and studied the drawings so that the description and operation of the device are understood, the Examiner takes up the claims.

If the invention is one of simplicity, the Examiner may read all the claims, or he may read only the broadest claims to see what scope the inventor or his attorney has endeavored to cover. The Examiner then goes to his file of prior United States patents, which is being continually kept up to date as patents are issued, and begins his search for references upon which the claims of the application may read. If he does not find any prior United States patent meeting the claims, he looks through his file of foreign patents, which is also kept up to date by exchange of copies of patents between the principal nations. If there is neither a prior United States patent nor a prior foreign patent that meets the claims, the Examiner may look into prior publications, books, etc. He usually notes the references on the margin opposite each claim he rejects, and usually places two horizontal marks opposite the claims he will allow.

### *The Official Action*

Having completed the examination of the case, the usual practice is for the Assistant Examiner to take up the case with the Principal examiner and

briefly outline a proposed Official action. The Principal Examiner makes such suggestions as he thinks proper and the Official action is then written. This is a letter in the name of the Commissioner addressed to the attorney of record. An unsigned carbon copy is sent to the attorney. The original letter is signed by the Principal Examiner and placed in the Official file wrapper. This letter designates the case by the inventor's name, serial number, filing date, and subject-matter of the application, and the body of the letter comprises the Examiner's action on the case. Just before the copy of the letter is placed in an envelope to be mailed to the attorney, both the original and the copy are stamped with a dating "Mail Stamp". This date is the official controlling date of the action. The law at present requires that response to such action must be made within six months from this date, otherwise the application is abandoned, that is, it is dead and the case is closed; under very special circumstances, it may be revived by order of the Commissioner.

### *"Objections" and "Rejections"*

The examination of the application is its first test. It is very rare that a case is allowed on the first action. An experienced attorney usually draws claims sufficiently broad to require the citation of art by the Examiner in order that the file of the case will show the nearest prior art known, so that should litigation arise on any patent granted on the application, it may be pointed out to the Court that notwithstanding this prior art, the Patent Office found the invention as claimed, to be novel and granted the patent. In other words, the citation of art which is overcome in a case has the advantage to the patentee of being a record judgment by the Patent Office in favor of patentability of the invention over the prior art cited. There are broadly two types of criticism which may be made by the Examiner, the first being "objections" to formal matters, the second being "rejections" to matters relating to the merits of the case. All actions by the Examiner are based either upon the Patent Statutes or the "Rules of Practice" which are based on the Patent laws.

Many things may be wrong with an application since the requirements of patent law are extremely technical. We will endeavor to point out some of the difficulties which may be encountered, and will take up now a few of the points which arise on the face of the application and which are not concerned with the merits of the case.

Under the present laws, the Government filing fee of thirty dollars covers a case containing twenty claims or less. The fee is increased one dollar for each claim over twenty in the case. Where an application has more than twenty claims and only a fee of thirty dollars is forwarded, the case will be held to be incomplete and will not be given a serial number and filing date until the proper full fee is paid. Attempts have been made to avoid this requirement of the law by filing an application with twenty claims and then immediately filing a paper adding additional claims before the Examiner has acted upon the case. Under these conditions, notice is promptly sent out that unless a fee covering the additional claims is forwarded, the case will not be acted upon but will become abandoned within six months from date of the notice. This action is a "rejection." Such additional claims as may be deemed necessary to protect the case may be filed after an action on the merits by the Examiner. No additional fee is required for such claims until the final fee is paid for the issuance of the patent.

The oath must be under seal. If the seal of the notary is omitted, or where the oath is incomplete, the case will be "rejected" and no patent will issue thereon until a proper oath is filed. If more than three weeks elapse (except as to cases executed abroad in which case longer time is allowed) between the execution of the oath to an application and the filing of the same in the Patent Office a new oath will be required based on the date of filing in the Patent Office. The reason for this requirement is that the applicant swears his invention has not been in public use, etc., for more than two years prior to filing his application. This fact might be true at the time he executed the oath, but might not be true six months from that date. Where filing a case is delayed for some reason after the case has been executed, it is usually best to file the case with the first oath and either attach another oath thereto or promptly file a second oath in which the critical fact dates are reckoned from the filing date. The advantage of retaining the stale oath is that it makes a sworn record, which while not acceptable for the purpose intended, may be valuable evidence to fix the date of invention should litigation arise.

The drawings must be on sheets of pure white Bristol Board (lightweight cardboard with a smooth finished surface) exactly ten by fifteen inches in size. A black border line one inch from the edge of the sheet encloses an area exactly eight by thirteen inches, and all the lines of the drawing including the signatures must be entirely within this border line. A clear space of not less than one and one-quarter inches must be left blank at the top of each sheet. This space is used for a proper heading on the drawing when the patent is granted. Each sheet of drawings must be signed in the lower right hand corner with the name of the inventor and the attorney. The drawings must be made with ruling pen and India ink. Free hand work to be acceptable must be unusually good. All lines, regardless of fineness, must be dead black, clear and sharp. All figures of the drawings on the same sheet must stand in the same direction, and preferably, should stand so that they may be read when the sheet is in an upright position. For views longer than width of the sheet, the sheet may be turned sidewise and the view placed lengthwise of the sheet. The required clear space, however, must be maintained at the narrow end of the sheet, which in the case of the view running lengthwise of the sheet, must be at the right hand end of the sheet. It occasionally happens that a very long machine cannot be shown on one sheet. In that

case, the machine is broken and a portion is shown on one sheet and another portion on a different sheet. The drawings are purely illustrative and dimensions are not required. In fact, unless dimensions are of the essence of the invention, dimensions on a drawing are objectionable and will not be permitted. The drawings must be transmitted to the Patent Office flat. If they are folded or broken, new drawings will be required. Unless the drawings meet these requirements, an "objection" to the drawings will be made in the first action.

If the application when filed is not accompanied by proper drawings as above specified, two things may happen. First, if the drawings submitted are blueprints, or are completely informal, as being on paper not of the proper kind or size specified, or drawn by free hand in a crude way, the applicant may be informed that his application is incomplete and unacceptable; that it will not be given a filing date or serial number. Such a case must be completed within six months, otherwise it will be held to be abandoned and the Government filing fee will be lost. This is a "rejection" for lack of completeness. When such a case is properly completed, it receives a filing date and serial number as of the date when it was completely filed in the Patent Office. Second, if the drawings are of proper size but are crudely made, or if the drawings are of proper size and are lithographs or prints, or if they are broken or torn in the mail, they may be received for purposes of examination only. New drawings will be required before the patent is issued. In this case, the application is given a filing date and serial number when filed and is held to be a complete application but the drawings are held to be informal, in other words, they are subject to "objection." The same ruling may apply to drawings made of colored ink. Such drawings may be acceptable for purposes of examination, but will be held to be "objectionable," and new drawings will be required before any patent will be granted, even if all the claims of the case were allowed. The drawings must illustrate every feature mentioned specifically in the claims, otherwise the claims will be "rejected" as not supported by the drawings.

The specification must be on legal size paper eight by thirteen inches with the subject-matter written or printed on one side only in permanent ink. Preferably, the lines (if typewritten) should be spaced at least two line widths apart. Single spacing is objectionable because there is not enough space between lines to enable the Clerk to enter corrections. Most specifications are now typewritten although the files of the older patents show all the papers to be in long hand. Specifications and claims if plainly written in long hand will be accepted today providing the ink used is permanent ink. Regardless of how the specification is prepared the ink used is tested, if it looks at all doubtful, and if it is found to fade under the usual bleaching tests for ink, then the specification is "objected" to and all subject-matter written in fugitive ink must be rewritten with record ink. No interlineations or erasures should appear on the specification or claims unless they are initialed on the margin or referred to in footnotes on the same sheet of paper.

The Rules require that an application begin with a preamble stating the name, citizenship, residence and Post Office address of the applicant; title of the invention and usually a power of attorney. The Post Office address of the applicant should differ from the address of the attorney in order that the Patent Office may communicate directly and independently with the applicant if it so desires. These requirements should be followed by a general statement of the object and nature of the invention; short, brief descriptions of each view of the drawing; a detailed description or specification, and the claims. If any of these formalities are omitted, as for example, suppose the brief description of the drawings is omitted from the specifications, this will be held to be "objectionable" and the Examiner will require that the short descriptions be inserted. If misspelled words occur in the specification or if reference numerals in the specification do not agree with reference numerals on the drawings, or if one reference numeral has been used to designate more than one part in the specification or on the drawings, these errors are all subject to "objection."

The patent laws require that an applicant for patent on an invention "shall file in the Patent Office a written description of the same, and of the manner and process of making, constructing, compounding, and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art or science to which it appertains, or with which it is most nearly connected, to make, construct, compound, and use the same; and in case of a machine, he shall explain the principle thereof, and the best mode in which he has contemplated applying that principle, so as to distinguish it from other inventions."

If the description in the specification is clear, concise, and not too verbose, little difficulty will be encountered in the Patent Office with the specification. There are a few old patent specifications which contain poetry. Today, definite technical language must be used, and poetry left to its proper place in literature. The Patent Office, however, is liberal as to the language which the inventor may use to explain the invention, provided, of course, that the language is not misdescriptive. Unusual words are often used in a specification, but if the definitions of these words be looked up, it will be usually found that the strange word has a meaning which specifically fits the situation. Some of the words which we may meet are, for example, "ungula" meaning that which is left of a cylinder or cone when the top is cut off oblique to the base. It was used in a patent on a headlight lens. Another is "chatoyant" meaning having a changeable luster like silk. "Conchoidal" referring to a lens defines a surface made up of one-half spheres, literally "shell-like". Another unusual word "nutation" defines a movement like the wobble of a top.

It is such a movement as is to be found in the moving parts of certain types of water meters. These words are merely chosen at random, as examples, but they illustrate that carefully chosen words having definite exact meanings in the specification carry precise meanings into the claims. To this end, it is not unusual to find "coined" words used in a specification. Where a situation arises, for example, in metallurgy, wherein a number of elements are related but do not belong to the same class or group, or in a chemical case, where a number of unrelated chemicals perform the desired function but otherwise are unrelated, the specification may list these several materials and then designate the entire group in some arbitrary way; for example, it may be put in this way:—"For the purpose of the present invention, molybdenum, vanadium, tungsten, and chromium, are designated as the —R-group of metals—". This type of description or definition when properly used, will be accepted by the Patent Office and in this way, an element of a claim may be set forth as "A member of the R-group of metals" which covers the individual metals of the groups without a recitation of alternatives which is not allowable in a claim. In other words, by this procedure of making definitions in a specification, it is possible to cover in the claims a scope which could not otherwise be done. The main thing which the Patent Office looks to in a specification is definiteness and clarity, and precise words not only are acceptable but are welcome.

If the specification is so inadequate as to fail to explain the invention to one skilled in the art, the Examiner may "reject" on the ground of indefiniteness. This may raise a serious situation because it may not be possible to cure the defect without introducing "new matter" which will not be permitted. In such a situation, it may be best to promptly file a new application properly prepared to cover the invention.

Trademarks used as descriptive terms as in a specification or claims are objectionable, for example, in place of "Bakelite," "Kodak," or "Vaseline," the specification should state—a phenol condensation product—a camera—a petroleum derivative. The use of trademarks will be permitted if the name is quoted and capitalized, or if followed by "(a trade mark)". The reason for this objection by the Patent Office is that very valuable trademark rights may be lost should such a mark become a descriptive name to designate an article of commerce and the Patent Office is desirous of cooperating to preserve these trademark rights to their proper owners.

### *Claims*

The patent laws of 1790 and 1793 did not require claims. When a patent was litigated, the Court had the duty of finding the features of novelty which the patent covered and this often entailed great labor and careful analysis. The law of 1836 was the first statute making claims a formal requirement. However the adding of claims to a specification was a general practice long before it was a legal requirement. The present statute requires of an applicant that "he shall particularly point out and distinctly claim the part, improvement, or combination which he claims as his invention or discovery." The claims of an application are short numbered paragraphs at the end of a specification which define the invention in technical language. When a patent issues, the claims define the scope covered by the patent, just as the metes and bounds in a deed for land define the boundaries covered by the deed. Most inventions are of such character as to present several novel aspects and, therefore, it usually requires more than one claim to properly define the novel scope thereof. The Courts have stated that it is the duty of the Court to interpret the claims of a patent but that the Court has no power to rewrite the claims to cover what might have been covered if the claims had been properly drafted. Therefore, it is the usual practice to submit very specific claims that cover the invention in the specific form disclosed in the application, and to also submit other claims which will cover the spirit of the invention when embodied in structures other than the specific form disclosed.

The claims in an application receive the most careful consideration in the Patent Office, and are the chief bone of contention in the Court. The claims are the real essence of the patent. The specification and drawing are merely the foundation on which the claims must stand. It occasionally happens that an application is filed without claims. In that case, the application is "rejected" as informal. The same action is given where the applicant writes what he believes to be "claims," but which are in fact a lauditory advantage set forth for his invention such as, "I claim—The best scrubbing brush ever invented"—or "I claim, A shock absorber that smoothes out all the bumps in the road". These "claims" may be all right in an advertisement but they do not define an invention by claims such as the patent laws require.

There are two types of claims acceptable by the Patent Office. In one type, (the United States type), each claim is a separate, distinct, paragraph defining a definite characteristic of the invention. If the invention is a machine, the claim usually defines a group of mechanisms as for example:

> A speedometer comprising a rotatable drum, colored bands on said drum, each band comprising complemental color stripes arranged in alternation, and a shaft whereby the drum may be rotated.

The other type of claim is known as the British type where one claim may be dependent on another, for example:

> 1. An automatic stop for phonographs comprising a rotatable record table provided with a spiral groove having substantially the same pitch as the tone groove of a standard record, and means cooperating with the spiral groove to stop the rotation of the record table when a standard record has been played.
>
> 2. An automatic stop for phonographs ac-

cording to claim 1 and wherein the said means comprises a shoe in engagement with the said spiral groove, and brake mechanism connected to said shoe.

The Patent Office will not allow claims of the British type to be built up pyramid fashion. That is, if claim two is built up by referring to claim one, claim three cannot be made up by referring to claim two. Such claims will be "rejected" as informal. It is all right for claim three, four, or as many claims as are deemed proper, to refer back to claim one or to some other base claim, but not to a sub-base claim.

The British type claim has the advantage of ease in writing, and of clarity in distinguishing sub-base claims from the base claims. This type of claim has the disadvantage of weakness in case the base claim is rejected or anticipated. In that case, the sub-base claims are seriously weakened and may be held met (by prior art references) or invalid. The British type is also inconvenient in the Patent Office prosecution in that should the basic claim be rejected and cancelled during prosecution of an application, the sub-base claims must also be cancelled because when the base claim is gone, the sub-base claims have no base claim to stand on. Also if an unnecessary limitation be in the base claim, this limitation is carried into all the sub-base claims because the sub-base claims are merely more specific claims that include everything in the base claims plus specified additions. Both the British type and the United States type of claims have their proper place when used by one versed in patent law.

### *"Broad" and "Narrow" Claims*

Claims are said to be "broad" or "narrow" dependent on their scope. A very broad claim, in the nature of a "basic" claim can only be based on an invention which is a pioneer in an art and this is a somewhat rare occurrence today.

The following claim selected from an unexpired patent is a broad claim:

"The method of producing sound comprising producing super-audible air pulsations, and controlling the pulsations at audible frequency to produce sound."

Such a claim may be said to be "basic" in that it defines an invention which is the beginning of a new art and is not an improvement on any existing type of sound producer. This method claim is based on the specification and drawings of a radio loud speaker. The patent also contains claims to the mechanisms. Method claims, when properly allowable, usually afford broader protection than structural claims. However, not every case is capable of supporting method claims.

A narrow claim is more or less specific to a particular disclosure and has a narrow scope. We will learn more about the scope of claims when we discuss patents in litigation. An example of a narrow claim is as follows:

"In an exposure meter adapted for use with light sensitive material, casing having an exposure opening therein, a support for a ring of light sensitive material, a ring of light sensitive material carried by said support, means to cause the support to advance the ring step by step beneath the exposure opening, a driving mechanism, an indicator driven by said mechanism, a scale comprising indices of a factor of plate exposure through a camera lens, and devices to start said mechanism to operate when said support is moved one step."

The exposure meter covered by the patent from which this claim was taken belongs to a well known type of exposure meter, and is an improvement on this kind of meter. The state of the art therefore made it necessary to limit the claim.

It is very common to find in a single patent claims of widely varying scope so that since the terms are only relative, such a patent may be said to contain both "broad" and "narrow" claims. The Patent Office has no objection to the scope of claims, provided, of course, they define a novel structure.

The formation of the claims and the breadth of protection sought is strictly up to the applicant or his attorney. It is the duty of the Examining Corps to examine cases, not to draft claims. If the claims presented for examination do not adequately protect the invention, it is not the province of the Examiner to draft broader claims. He simply acts on what is presented and assumes either the applicant knows what he is doing or that he has employed a competent attorney who knows how to properly protect the invention. Occasionally, the Examiner may make suggestions as to the change of a word or two or a phrase in a claim, but this is just to clear up some minor difficulty. There is a story told of an Examiner (a political appointee before the days of Civil Service) long since gone to his fathers, who laboriously wrote in long hand a long letter of criticism to an attorney telling him how many things were wrong with a claim in the case. He then wrote out a claim which he suggested be substituted for the one in the case. After he had finished his labors, he turned to an associate and said: "I couldn't find a reference for the claim he submitted, but if he makes the claim I suggested I know where there's a reference." That was in the "good old days". The Patent Office does not do business that way today. The Examining Corps are very technical in their actions. At the same time, they are a wonderful body of fine men who are very conscientious in their work.

### *Division*

If the specification and the claims cover a plurality of inventions, as, for example, a case discloses an automobile and the claims cover both the engine and the braking system, the Examiner will reject on a requirement for "division". This means the applicant must elect to limit his original application to one of the inventions disclosed. He has the right, however, to file a "divisional" application, covering the inventions which he disclosed in, but has been compelled to divide out of, his original

application. A "divisional" application, while having a filing date and serial number as of the time when it was filed, gets the benefit of the filing date of the original application so far as the subject-matter of the divisional case is identical or common to the original case, when it comes to references, and the filing date of the original is its record date for all purposes in the Patent Office.

If the invention is simple and the attorney has drawn an unreasonable number of claims which are of substantially the same scope but vary one from the other only with respect to language, the Examiner may refuse to go to the labor and trouble of examining unnecessary claims and may "reject" on the ground of "multiplicity of claims".

*Multiplicity of Claims*

It is a mistaken idea to assume the more claims in an application, or patent, the better. It is sometimes very easy to write a large number of claims by merely changing the phraseology or wording of one claim from another without really changing the scope. Such claims are usually easily anticipated because if a reference is found for one of the group of such claims, the whole group is liable to fall since there is little difference in scope between the claims. It is much more difficult to write a few carefully considered definite claims of varying scope commensurate with the novelty of the invention, but such claims are much more difficult to anticipate and are worth the time and labor necessary to frame them. It often requires many hours of hard study and careful analysis to formulate a single claim that fully defines an invention in view of the prior art. Such a claim must fully cover the invention but must not read on any prior art publication, patent, or device. An application on a simple invention with a dozen carefully drawn claims to cover various aspects of the invention will receive more consideration in the Patent Office than the same application with a hundred colorless claims. The same psychological effect is to be encountered in the Courts. Where a Judge must consider a patent having a large number of claims that differ only by colorable language (all claims in a patent are legally presumed to be patentably distinct one from the other), the only process of searching for microscopic differences between such claims is very laborious and this naturally has a tendency to arouse the feeling that the alleged invention is more a matter of language than substance, to the great detriment of the patentee.

A net finely woven of small threads may be nice to look at, but the one strongly woven of heavy cords with wider mesh catches and holds the bigger fish. Of course, a complicated mechanism like a calculating machine, or a complicated electrical apparatus may justifiably carry many claims. Even in the case of very complicated devices, it is usually possible to break up the essential features of the machine into relatively simplified sub-groups of mechanisms and to cover each of these sub-groups of mechanisms with separate applications for patent, each having relatively few claims. The Patent Office officials will be much more tolerant with five cases on sub-group devices each carrying a dozen claims than they will with a single case with fifty claims on the whole machine. This breaking up of a machine into sub-group patents also has a great advantage in litigation. Instead of being compelled to bring a voluminous patent on a whole machine into Court, suit may be brought on a single patent on a relatively simple group of devices which may be easily explained and clearly understood. Thus it becomes easier and simpler for everybody and the issues are clear and distinct.

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## Recent Changes Made in The Superheater Company

M. Schiller, in addition to his duties as vice-president of The Superheater Company of New York and Chicago, has been elected treasurer of that company, to succeed W. F. Jetter, recently resigned. F. J. Dolan was elected assistant secretary and assistant treasurer of the company.

Thos. F. Morris was elected treasurer and assistant secretary of The Superheater Company, Ltd., of Montreal, to succeed W. F. Jetter.

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**The Tenth Annual Convention and Show** of the oil burner industry will be held in Chicago at the Hotel Stevens during the week of June 11, 1933, in conjunction with the opening of the "Century of Progress," according to announcement by Morgan J. Hammers, President of the American Oil Burner Association upon his return from Erie, Pa., where the directorate of the Association held its regular quarterly meeting.

"In view of the fact that the oil burner is a product typical of those which mark America's 'Century of Progress'," Mr. Hammers said, "it seemed entirely fitting to our directors, after reviewing the wishes of our industry as a whole, that the oil burner industry should celebrate the tenth anniversary of its public shows coincident with the opening of this great international exposition."

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**Kieley & Mueller, Inc.,** New York, has appointed the F. G. Hartley Co., Perkins Building, Tacoma, Wash., agent for its full range line of pressure control devices and allied specialties in the Pacific Northwest.

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**The Riley Stoker Corporation** announces that George G. Van Tuyl has been appointed District Manager of their Cleveland, Ohio, office, beginning September 1, 1932.

# Central Arizona has Unusual Construction Features

**The Steam-Electric Station of Central Arizona Light and Power Company is unusual in that two sides of the boiler room are open to the weather. The plant has shown a monthly heat consumption of 14,500 B.t.u. per kw-hr. net station output with average throttle steam conditions of 380 lb. gage, 677 fahr. and a circulating water temperature ranging between 61 and 80 fahr. Bad well water necessitated an elaborate water-treating system. . . . The article gives complete details of equipment, and performance data.**

By W. F. FRIEND and E. H. KRIEG

Engineering Department

Electric Bond and Share Company, New York

CENTRAL Arizona Light and Power Company purchases the major portion of its power supply from the hydro-electric system of the Salt River Valley Water Users' Association, a corporation of land owners operating an irrigation system constructed originally as the Roosevelt Project of the U. S. Reclamation Service. Several dams were constructed for irrigation storage and power development on the Salt River, utilizing the head existing in the main irrigation canals. The hydro-electric power is sold to the large copper mines, and to other power consumers including the Central Arizona Light and Power Company, which serves the City of Phoenix and other towns and territory in central Arizona.

In March, 1929, it became evident that a continuation of the drought, which had existed for several years, would completely exhaust the stored water by April, 1930, with resultant scarcity of power. The Association in such event would be unable to meet its commitments for firm power including that to the Central Arizona Light and Power Company. Prompt action was necessary to meet the temporary need of the Association and since the Power Company would in the course of years require additional capacity, it constructed the Central Arizona Steam-Electric Station, which is operated for the joint account of the two interests over a period of years. As pointed out in the June 15, 1929, issue of the "Electrical World," the "whole set-up constitutes one of the finest examples of sensible cooperation in power development on record." Construction work was started in June, 1929, and the 15,000 kw. station was placed in operation in April, 1930.

An extensive search for a suitable site led finally to a location three miles west of Phoenix, Arizona, and two miles north of the Salt River. It adjoins the main line of the Southern Pacific Railroad and a principal county highway. Of the 160 acres that were secured, 62 are designated as the station grounds. The mean elevation of the property is 1051 ft. above sea level.

*Station Structure*

The climate appeared to be suitable for the construction of an outdoor boiler room, and cost analyses were made for various arrangements. It was found that the all-outdoor boiler room could not be justified, as the saving would be too small to compensate for the disadvantages; hot sun, rain and sand storms would be encountered. However, it was decided to leave the sides of the boiler room open with the exception of the permanent side facing the prevailing winds.

Instead of building a separate wall between the turbine and boiler rooms, the rear boiler walls were used as a portion of the curtain wall, and the remaining area was bricked in with a support separate from the boiler walls. This arrangement permitted a saving in that the usual aisle between the boilers and fire or curtain wall could be omitted.

It also simplified taking the air supply for the forced draft fans from the auxiliary aisle via the air-cooled furnace floor, thus providing ventilation for a portion of the building where excessive temperatures ordinarily prevail.

That the resulting structure had a pleasing appearance is shown by Fig. 1 and by the view on the front cover. This is due somewhat to the turbine room roof having the same elevation as the boiler room roof, as shown in Fig. 3. The exterior walls are of gunite on expanded metal, three coats being applied to the exterior and one to the interior, giving a total thickness of 1½ in. This is colored by two coats of light buff cement paint brushed on the exterior, with ornamental details painted oyster shell white.

The gross building volume measured to outside

dimensions and from the top of the floor slab to the top of the parapet walls is:

| | |
|---|---|
| Boiler room .................. | 288,000 cu. ft. |
| Auxiliary bay ................ | 181,000 cu. ft. |
| Turbine room ................. | 357,000 cu. ft. |
| | 826,000 or 55 cu. ft. per kw. |
| Electrical bay ................ | 42,000 cu. ft. |

The foundations comprise continuous wall footings and individual and compound column footings resting on soil good for a loading of 5,000 lb. per sq. ft.

The light-weight roof consists of Robertson V-beam asbestos metal decking resting on structural steel purlins, with two ½ in. layers of Insulite board and Johns-Manville built-up felt roofing.

On the roof of the boiler and turbine rooms are mounted nine 48 in. Ilg, power-type ventilators with automatic self-closing louvers. Each is rated at 18,400 c.f.m. and driven by a 1.5 hp. motor.

In the fundamental design of the station, provision is made for future adoption of pulverized coal, if conditions should alter so that coal is more economical than oil. Thus, space in the yard has been allocated to future coal storage while locations of spray ponds, oil storage facilities, the extensive water treating plant and miscellaneous structures have been determined to allow an economical layout of coal handling and preparation plant. It is contemplated that a bin and feeder system would be used, the raw coal bunkers and pulverizer plant to be installed in a building parallel to the boiler room and over the present underground concrete flue gas tunnel which was adopted in lieu of the more usual overhead breeching with this plan in mind. The pulverized coal bins would be placed in line with the economizers which were purposely made shorter than usual to give the necessary endwise clearance. Reconstruction of furnaces to secure suitable ash hoppers has been provided for in the present design, such as low side water walls that would come below a future hearth screen. In the arrangement of spur tracks and sidings, a flexible basic layout was adopted so

**Fig. 1—View of station showing open end of boiler room.**

that future trackage requirements with either coal or oil could readily be met.

For the present, oil storage is provided in a diked 55,000 gal. umbrella-top tank, but space is reserved for several additional tanks if required by future plant extensions or the condition of the fuel oil market. At the station are placed two service tanks with interlocked oil control valves for quick throwover, to permit accurate determination of station fuel consumption volumetrically by gaging.

Space above the offices at the north end of the turbine room is available for storage of spare parts or for a workshop in making equipment repairs, the floor having been designed for suitable live loading. The main turbine room crane is available for handling materials to and from this area. Similarly, the crane can be used for transporting oil switches and transformers located on the upper level of the auxiliary bay, also for untanking future 66 kv. transformers in the unoccupied space at the end of the turbine room, as well as for pulling the generator rotor into and out of the stator for inspection and maintenance.

### *Yard Building*

Before work was started, a Truscon standard building was so located that after serving as a construction building it could later be used for storage purposes, for the machine shop, for housing equipment for the water-treating system, and for the chemical laboratory. It is 40 by 112 ft., and 11.5 ft. clear height under roof trusses.

### *Combustion Control*

Combustion is controlled by hand regulation of oil pressure at the burner manifold and by hand regulation of air pressure in the burner wind box. To assist in the latter, the forced draft fan has 60 per cent speed variation in thirteen steps. The push-button control is conveniently mounted on the individual boiler gage-boards. Final air-pressure regulation is obtained by a motor-operated damper at the fan outlet, the push-button station being located on the same gage-board as the forced and induced draft fan control. The induced draft fans are two-speed, the control being on the individual boiler gage-boards.

Furnace pressure is automatically held at a predetermined uniform value by a Leeds & Northrup air-bell device with electrical contacts controlling the motor-operated damper at the induced draft fan outlet.

### *Unusual Provisions*

Boiler feed is heated and deaerated by vapor from the single-effect evaporator, thereby eliminating a high-heat-level (evaporator) condenser.

Leak-off steam from the high-pressure turbine packing is taken into the tenth stage bleeder piping directly at the turbine extraction opening, making a separate gland steam leak-off condenser unnecessary.

The Limitorque motor-operated valves at the circulating water pump discharges are interlocked with the pump motors so that upon loss of voltage or tripping out of the motor, the corresponding

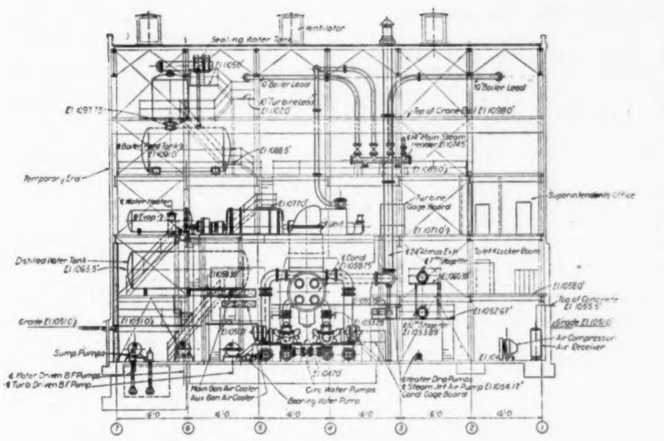


**Fig. 2—Cross section of turbine end of station.**

valve will automatically close in 40 seconds, thus preventing reversal of flow from the other pump and possible shut-down of the plant. A cross-connection is provided so that either pump may supply water to both halves of the condenser (which has divided water boxes) when the other pump is out of service.

The auxiliary generator air cooler, an oil cooler and the steam jet air pump are supplied from the condenser circulating water system.

The 105-kw. direct-connected exciter has a 5-kw. direct-connected sub-exciter which eliminates the usual motor-operated main field rheostat.

Station auxiliary motors 50 hp. and over are 2200 volt; 40 hp. and under are 220 volt.

The induced draft fan discharge duct incorporates a 50 per cent cone for recovering velocity head. It connects to the top of the underground breeching as shown by Fig. 3.

To economize service water which must all be pumped from wells and lime-treated to prevent plugging piping with deposits even in cold water lines, provision is made for collecting all overflows from water-cooled bearings, oil coolers, drains, etc. and pumping them as make-up to the spray pond. When floors are cleaned, condensers washed, or the collected water is otherwise contaminated, it can be discharged overboard to the sewer.

Provision is made in the connection at each end of the wood stave lines to permit both of them to be used for condenser discharge in the future, at which time a new line would be constructed to serve as condenser inlet. An addition to the spray pond would, of course, be required and the present units are laid out to permit logical development.

In Arizona, algae formation almost invariably appears in cooling towers and spray ponds. This is difficult to combat with copper sulphate as there is no satisfactory means for determining the proper dosage. A chlorination system was therefore incorporated as a part of the water-treating plant.

### *Operating Difficulties*

Although only eleven months were available for the combined design and construction period, all operating difficulties were ironed out within a few months after the station was placed in initial operation.

The original downtake furnace wall was of 18 in. thick refractory brick in which the burners were placed. Failure of this wall, due chiefly to expansion difficulties, led to replacement by suspended-type refractory similar to that used to back the water walls.

During the first months of operation, numerous condenser tube failures occurred but the exact cause has never been definitely determined. It is thought that this trouble may have been caused by the circulating water conditioning being out of control for perhaps a short interval of time, since there was no recurrence of tube failures after the station was "tuned up".

No other troubles than the two mentioned were of any great significance.

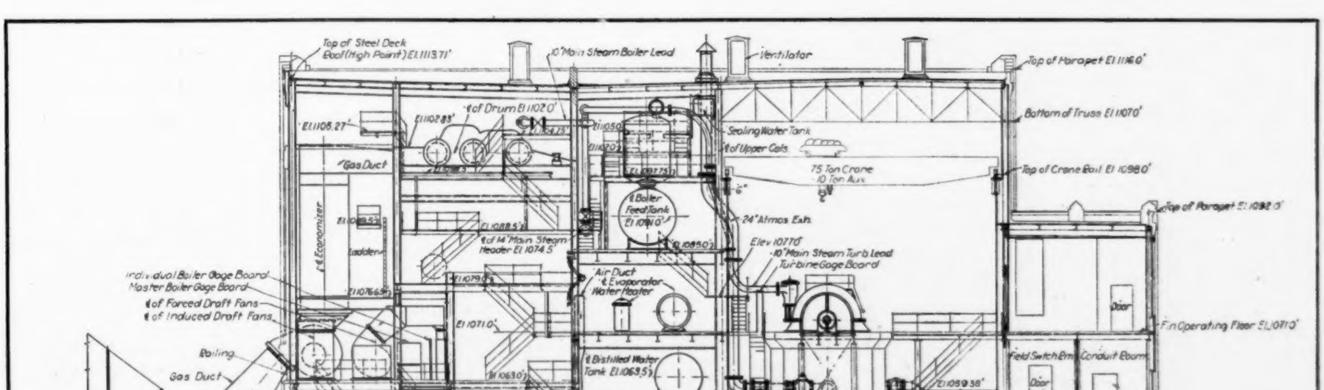


**Fig. 3—Longitudinal section of station.**

*Monthly Performance*

Operating figures for one month's performance are:

| | |
|---|---|
| Average hourly output, kw-hr | 12,888 |
| Energy to plant uses, per cent | 5.0 |
| Power factor through max. hr., per cent | 99 |
| Station load factor based on max. hr. gen., per cent | 63 |
| Station operating capacity factor, per cent | 90 |
| Station serviceability factor, per cent | 100 |
| Av. steam pressure, lb. per sq. in. | 379 |
| Av. steam temperature, fahr. | 677 |
| Av. abs. pressure exhaust, in. Hg | 1.5 |
| Inlet circ. water temp., max.-min., fahr. | 80-61 |
| Av. temp. feed to boilers, fahr. | 331 |
| Av. temp. feed to economizer, fahr. | 256 |
| Heat added per lb. steam, blr. and econ., B.t.u. | 1125 |
| Total make-up water, per cent | 2.7 |
| Heat value per lb. oil, B.t.u. | 19,000 |
| Boiler efficiency, blr. only, per cent | 75.5 |
| Boiler efficiency, incl. economizer, per cent | 81.6 |
| Steam per kw-hr. net station output, lb. | 10.5 |
| B.t.u. per kw-hr. net station output | 14,482 |

The man-hours required for this month of 744 hours were:

| | |
|---|---|
| Office and supervision | 700 |
| Operation | 3600 |
| Maintenance | 800 |
| Total | 5100 |
| Average number of employees | 6.85 (all departments) |

*Equipment*

***Turbine-Room Equipment***

**Tubine-Generator**

Make ................General Electric Co.
Size ................15,000 kw. at 80 per cent power factor, 18,750 kva. with full bleeding
Turbine stages ......14
Throttle conditions ..375 lb. gage, 725 fahr. normal, 750 fahr. max.
Bleed points ........1st, 7th and 10th stages
Generator voltage ..12 kv., 3 ph., 60 cyc.
Exciter .............Direct-connected, compound-wound, 105 kw., 250 v.
R.p.m. ..............1800

**Air Cooler**

Make ................General Electric Co.
Main section ........6750 sq. ft., 3-unit supplied with turbine condensate
Auxiliary section ....4500 sq. ft., 3-unit, supplied with condenser circulating water

**Surface Condenser**

Make ................Worthington
Sq. ft. .............16,000 in ⅞ in. Admiralty tubes, 21 ft. long
Type ................Two-pass with divided water boxes

Tubes are expanded into sheets at both ends, the center plate being spring-supported to care for expansion. The turbine connection is rigid, the shell being mounted on springs resting on concrete piers.

**Circulating Water Pumps**

Make ................Worthington
Type ................18 in. single-stage, double-suction
Capacity ............20.6 c.f.s. each at 57 ft. head
Motor ...............G-E. 200 hp., 900 r.p.m., squirrel cage

An 0.3 c.f.s. 75 ft. supplementary pump is provided to supply condenser circulating water to water-cooled fan bearings, etc.

**Condensate Pumps**

Make ................Worthington
Type ................3-stage, 6 in.
Capacity ............0.845 c.f.s. (190,000 lb. per hr.) at 300 ft.
Motor ...............G-E, 75 hp., 1200 r.p.m., squirrel cage

The hot well level is maintained by the condensate pump characteristic without float control or pressure-regulating valves.

**Steam Jet Air Pumps**

Make ................Worthington
Type ................Two 2-stage with common inter and after condenser with external raw water precooler
Capacity ............85.5 lb. air per hr. at 70 fahr. (19.2 c.f.m. free dry air each)

**Lubricating Oil System**

Coolers (2):
Make ................Griscom-Russell
Type ................2-pass vertical, multi-whirl, 231 sq. ft.
Cooling water .......1 with condensate, 1 with raw water

Filter:
Make ................Bowser
Type and size ......Bag, 1500 to 3000 lb. per hr., arranged for either continuous by-pass or batch treatment
Pumps ...............36 c.f.h. rotary filter pump, 280 c.f.h. rotary transfer pump
Precipitation tank ...Bowser, 267 cu. ft. in each of two compartments

**Miscellaneous Equipment**

Turbine room crane ..Cleveland, 75 tons, 45 ft.-10¼ in. span, with 10-ton auxiliary hook
Service air compressor ...............Worthington single-stage, 10 in. x 10 in., 110 lb. gage, with automatic intake unloader, air intake filter, and 2 ft.-6 in. by 7 ft.-0 in. receiver

**Pipe Flange Standards**

For the high-pressure steam and boiler feed lines, the 400-lb. A.S.A. standard with ¼ in. raised face flanges is used with 1/16 in. thick sheet packing gaskets.

***Auxiliary Bay Equipment***

**Boiler Feed Pumps**

Make ................Worthington, 5 in.
Number ..............1—motor-driven, 1—turbine-driven
Stages ..............4
Capacity ............275,000 lb. per hr. (1.3 c.f.s.) at 260 fahr.
Head ................475 lb.
R.p.m. ..............1750
Turbine .............275 hp. G-E., single-stage, D-54
Inlet steam .........400 lb., 750 fahr.
Outlet steam ........2 in. Hg. abs. to 40 lb. gage
Motor ...............275 hp., squirrel-cage, G-E

**Feed Water Heaters and Auxiliaries**

Make ................Foster-Wheeler
Service .............One each for 7th and 10th Stages
Area, sq. ft. each ...475
Passes ..............4
Length between tube sheets ........9 ft.-8 in.
Tubes ...............¾ in. o.d., copper
Shell working pressure, lb. gage ....75
Water box working pressure, lb. gage ..150
Terminal difference fahr. ..............5

The seventh-stage heater is drained into the shell of the tenth stage heater by means of a Stets float-operated controller. Drains from tenth stage heater (including seventh stage drains) are pumped into main turbine condensate line at inlet to seventh stage heater, by either of two duplicate Worthington two-stage centrifugal pumps rated at 0.14 c.f.s. (30,400 lb. per hr.) of water at 190 fahr. against 300 ft. total dynamic head, driven at 3510 r.p.m. by a 10-hp. squirrel cage induction motor. Discharge of pumps is regulated by float-operated balanced valve dependent on the level in the tenth stage heater hotwell.

**Deaerating Boiler Feed Tanks**

Make ................Elliott
Capacity, lb. per hr. ..600,000
Storage tank ........10 ft.-0 in. dia. by 20 ft.-0 in. long
Deaerating head .....8 ft.-0 in. dia. by 9 ft.-0 in. high
Vent condenser ......762 sq. ft.
After condenser ......97.5 sq. ft. for air ejectors during operation at sub-atmospheric pressure
Level alarms ........High and low-level float switches
Over-flow surge tank .............8 ft.-0 in. dia. by 25 ft.-0 in. long. Horizontal. Vented back to storage tank. When surge tank is filled, excess water is discharged to sewer.

Transfer Pumps:
Make ................Worthington
Capacity ............0.95 c.f.s. (200,000 lb. per hr.)
Control .............Started and stopped automatically by float switches on storage tank

**Evaporator System**

The 484 sq. ft. Foster-Wheeler single-effect evaporator receives steam from the turbine first stage and delivers 11,400 lb. per hr. of vapor to the deaerating boiler feed tank when supplied with 103 lb. gage steam and 150,000 lb. per hr. of condensate at 233 fahr. in the boiler feed tank. When bleed steam is not available, high-pressure steam may be supplied through a reducing valve.

A 24 in. square, 5 ft. 5 in. high Elliott, vertical open heater preheats the evaporator feed to 220 fahr. with evaporator vapor controlled by a thermostatic valve. A 2.5 sq. ft. vapor condenser, cooled by the heater inlet water, recovers the heat in the vented vapor.

Evaporator feed is treated by a 0.1 c.f.s. Permutit Zeolite softener and is stored in an 8 ft. dia. by 25 ft. tank in the boiler room basement. Duplicate Worthington pumps can deliver 15,000 lb. per hr. each to the evaporator heater.

### *Boiler Room Equipment*

**Boilers**

| | |
|---|---|
| Make | B. & W. |
| Number | 2 |
| Sq. ft. | 12,179 |
| Type | Stirling, Class XXIII |
| Max. allowable press. lb. gage | 405 |
| Max. output, lb. per hr. | 150,000 |
| Superheater outlet temp., fahr. | 750 |

**Superheaters**

| | |
|---|---|
| Make | B. & W. |
| Sq. ft. | 3900 of 2 in. o.d., 0.134 in. thick tubes |
| Type | Interdeck convection |
| Boiler connection | 12-4 in. o.d. tubes expanded into top of rear upper boiler drum |

**Economizers**

| | |
|---|---|
| Make and type | B. & W. return-bend |
| Sq. ft. | 7120 |
| Tubes | 2 in. o.d., 0.165 in. thick |
| Inlet & outlet temp., fahr. | 260 to 384 |
| Tube removal | Through one side |

**Furnaces**

Side Walls: Thickness—22.5 in. above waterwalls; inner facing—Walsh XX first-quality fire brick, outer facing—Vitrefax second-quality fire brick.

Downtake Wall: Suspended-type refractory similar to backing behind water walls.

Water-Walls:

| | |
|---|---|
| Make | B. & W. |
| Location | Both sides and uptake end |
| Tubes | 4 in. o.d. plain on 9 in. centers recessed 4 in. into 9 in. refractory backing |
| Surface | 1150 sq. ft. total |
| Insulation and casing | 9 in. refractory (recessed for tubes), 2 in. Superex block, 2 in. 85 per cent magnesia, steel casing |

Floor:—5 in. first-quality firebrick, 4 in. crushed brick, 2½ in. Sil-o-cel, ¼ in. asbestos millboard, ½ in. steel plate resting on 6 parallel 12 in. I-beams on bottom of which is ¼ in. steel plate forming 5 air ducts through which furnace air supply is drawn by forced draft fan.

Roof:—2 courses of fire brick laid on interdrum circulating tubes, 1.5 in. 85 per cent magnesia, 0.5 in. plastic finish.

**Forced Draft Fans**

A Buffalo double-width, double inlet fan supplies 50,000 c.f.m. of air at 140 fahr. to the burner wind box on each boiler against 3.2 in. static pressure at 875 r.p.m. The 60 hp. motor has a 40 per cent speed variation in 13 steps. The air supply is taken from the station auxiliary bay as previously described.

**Induced Draft Fans**

Each Buffalo double-width, double-inlet fan per boiler is rated at 100,000 c.f.m. at 478 fahr. against 6.5 in. water at 875 r.p.m. A two-speed squirrel-cage, 200/160 hp., 900/720 r.p.m. motor drives each fan. Final draft regulation is obtained by a motor-operated damper at fan outlet.

**Stack**

The Rust stack is of reinforced concrete 200 ft. above grade, 14 ft. I.D. at top, with a 4 in. brick lining for the full height with a 2 in. air space between it and the stack. The breeching below grade is of reinforced concrete with a 4 in. brick lining on floor and walls, with a 2 in. air space between. The roof insulation is 2.5 in. thick.

**Station Fuel Oil Equipment**

Each boiler has 10 Forney mechanical-automizing burners set in an 18 in. brick wall at the downtake end of the furnace. Each burner will supply a maximum of 20 lb. per min. at 250 lb. gage, 275 fahr. They are guaranteed to require not over 15 per cent excess air.

The burner fuel oil pumps, designed for 300 lb. gage, deliver 25,000 lb. per hr. each.

| Type | Size | Drive |
|---|---|---|
| One Dean Duplex piston | 8 x 4.5 x 12 in. | Steam |
| Two Quimby screw | No. 3½ | 25 hp. motor |

The two screw pumps each have a four-speed squirrel cage motor; the speed control stations are placed on the boiler room operating floor near the master boiler gage board.

Either of the two vertical heaters will raise 25,000 lb. of oil per hr. from 120 to 275 fahr. when supplied with 350 lb. saturated steam. The condensate is trapped into the boiler blow-off tank.

The burner pumps are supplied with oil under gravity by one 500 bbl. and one 1500 bbl. service tank in the yard adjacent to the boiler room. They are enclosed by 8 in. thick circular concrete dykes and have low-pressure steam-heating coils.

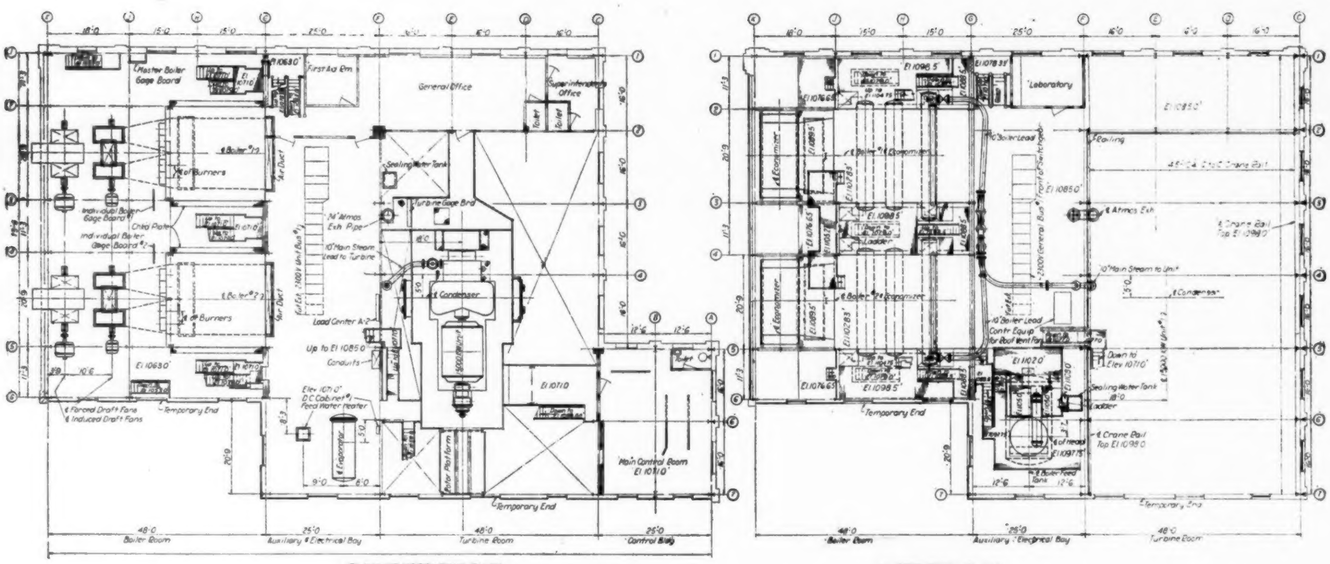
Oil consumption is measured by gaging the service tanks manually with a steel tape device. A remote indicating thermometer having a sensitive bulb submerged at the middle of the tanks indicates oil temperature.

**Blow-off Tank**

The 4 ft. dia. by 12 ft. long blow-off tank receives boiler and auxiliary blow-offs, water-wall drains, and oil heater trap discharge. Working pressure is 400 lb. gage; atmospheric vent is 10 in. dia. To receive the uptake water-wall drains which are too low to drain into the main blow-off tank, a 1 ft. 6 in. dia. x 4 ft. 0 in. receiver is provided.

**Water Supply and Treatment**

Raw water is taken from two 20 in. dia. wells about 175 ft. deep, each having a Byron-Jackson two-stage turbine-type pump rated at 5 c.f.s. against 98 ft. head and driven by a 100 hp. 1200 r.p.m., vertical, built-in motor. These discharge into the raw water settling basin at the water-treating plant.



PLAN OF OPERATING FLOOR
Elev 1065.0' & 1071.0'

CLERE STORY PLAN
Elev 1085.0'

**Fig. 4—Plan views of station.**

Because of the high concentration of salts in the well water, the entire water supply is treated to accomplish the following results:

1) Reduction of temporary hardness to the minimum possible value through conversion, by lime, of soluble bicarbonates into insoluble carbonates.
2) Stabilization of lime-treated water to prevent after-reaction in the piping system, station equipment and Zeolite softeners, through conversion by $CO_2$ of excess lime into insoluble carbonate.
3) Removal of floc carbonates by sand filtration.
4) Reduction of alkalinity in spray pond water to prevent precipitation of calcium carbonate in condenser as a result of built-up concentration, by introduction of sulphuric acid.
5) Sterilization of spray pond water to prevent growth of algae and slimes, by introduction of chlorine gas.
6) Reduction of total hardness in water used for evaporator feed to the minimum possible value, through exchange of scale-forming solids for soluble sodium salts, by Zeolite.

Capacities of the various portions of the equipment are:

| | |
|---|---|
| Lime treatment carbonation and filtration c.f.s. of water | 1.3 |
| Acid treatments, c.f.s. of water | 1.0 |
| Chlorination, lb. of chlorine per hr. | 25 |
| Zeolite softening, c.f.s. of water | 0.1 |

To accomplish the results desired, the major equipment provided comprises:

One concrete two-compartment basin equipped with tile sludge spider, for settlement of raw water and recovery of backwash water from sand filters.
Two raw water pumps, vertical submerged centrifugal type, each designed for 1.3 c.f.s. against 103 ft. head and driven at 1750 r.p.m. by a 30-hp. built-in squirrel cage motor.
One lime-settling tank 26 ft. dia. by 43 ft. high including carbonation chamber 8 ft. deep at top, equipped with motor-driven agitator, flue-gas grid and sludge spiders.
Two lime-mixing tanks, each 11 ft. dia. by 5 ft. high, with motor-driven agitators and proportional feed equipment.
Two lime feed pumps, single-stage centrifugal type, motor-driven.
Three sand pressure filters, each 8 ft. dia. by 10 ft. long.
Two motor-driven flue-gas compressors with scrubbers in suction lines.
One acid treating tank of wood stave construction, 11 ft. 6 in. dia. by 7 ft. high, complete with motor-driven agitator, dilution tank, proportional feed device and acid drum-handling equipment.
One chlorinator, vacuum type with chlorine cylinder manifold and 1½ in. dia. rubber discharge hose to spray pond.

Sludge from the treating plant together with waste water (exclusive of sanitary wastes) from the station building flows through a 24 in. line to a circular sludge receiving basin. This basin is 14 ft. dia. with an inside depth of 10 ft. and is equipped with a motor agitator for keeping the solids in suspension. Two vertical, submerged centrifugal pumps, each designed for 1.0 c.f.s. against 124 ft. head, are provided at the basin, with float control switches for automatic operation. These pumps discharge through an 8 in. cast-iron bell-and-spigot pipe line approximately 11,000 ft. in length to the Salt River, where leaching pools are provided in the stream bed.

After lime treatment, carbonation and filtration, the general station service water is pumped to a 10,000 cu. ft. tower tank 125 ft. high or directly to station building by one of two 0.5 c.f.s. pumps.

#### Condensing Water System

This includes a 41 c.f.s. spray pond connected to the condenser by two 48 in. Continental creosoted wood stave pipes, about 1040 ft. long, 5 ft. below grade. In the building, Class B flanged cast-iron pipe is used.

The spray pond is 141.5 by 396.5 ft. inside, with a depth of 5.5 ft. and a storage of about 110,000 cu. ft. A level variation of 2 ft. is allowed.

The entire bottom of the spray pond is floored with concrete, as preliminary tests showed that leakage losses through a puddled-type bottom would be excessive because of soluble constituents in the semi-caliche available. The concrete is sloped to afford drainage to a centrally located sump in each pond section, these being connected

to a sewer line, since frequent flushing out of the ponds may become necessary to eliminate sediment deposit if the water treating system should at any time get out of control.

To permit taking any section out of service, the pond is divided by cross-walls into three sections with a 5 ft. wide intake flume along one side. The intake chamber is equipped with two sets of 0.5 in. mesh stationary screens and a jib crane with a Wright hand-operated chain hoist. Grooves are provided for stop logs.

Each of the 384 Marley non-clogging nozzles is rated at 0.107 c.f.s. under 15.6 ft. head.

**Machine Shop Equipment**

16 in. x 10 ft.-0 in. Lathe; Tool grinder; 28 in. Shaper; Pipe threader, 2½ in. to 8 in.; 4 ft.-0 in. Radial drill; Hack saw, 8 in. by 8 in.; 20 in. Upright drill; Blacksmith forge; 14 in. x 2 in. Grinder.

**Oil Storage**

The 55,000 bbl. tank is 117 ft. dia. by 29 ft. high and rests on a graded earth foundation. It is enclosed by a 6 ft. earth dyke, 325 ft. square. Heating coils and standard accessories were provided.

The following oil unloading pumps adjacent to the storage tank are for 75 lb. gage:

| Type | Size | Drive | Lb. per hr. |
|---|---|---|---|
| Dean Duplex piston | 7.5x5x10 in. | Steam | 35,000 |
| Quimby screw | No. 3½ | 15-hp. motor | 35,000 |
| Quimby screw | No. 4 | 20-hp. motor | 80,000 |

The 8 in. oil line from the unloading track and pump house extends to the storage tank, service tanks and station building. A 1.5 in. rider pipe carrying low-pressure steam is carried directly on top of the oil line in the same heat insulation.

The oil line is of welded construction with tube-turn fittings to eliminate flanged or screwed joints wherever possible. Guided slip-type joints allow free expansion where flexibility by pipe bends was impracticable. A 2.5 in. line carries saturated steam at full boiler pressure from the station to the steam-driven pump and through a reducing valve to the heating coils in the 55,000 bbl. storage tank.

### *Electrical Equipment*

Instead of the customary electrical bay parallel to and the same length as the turbine room, Fig. 4 shows the comparatively small control room. As the turbine room was intended to require only two operators, an 80 drop annunciator was provided to indicate immediately the tripping out of any station auxiliary motor. It indicates automatic operation of all 12 kv., 2.3 kv., and 220 volt equipment. It is supplied from the 125 volt storage battery.

The main generating unit is direct-connected through oil circuit breakers to the 12-kv. outdoor buses. The generator leads inside the station are varnished cambric insulated, with special braid, mounted on 15 kv. porcelain bus supports and entirely enclosed in fireproof compartments.

The main switchboard is of the vertical type with

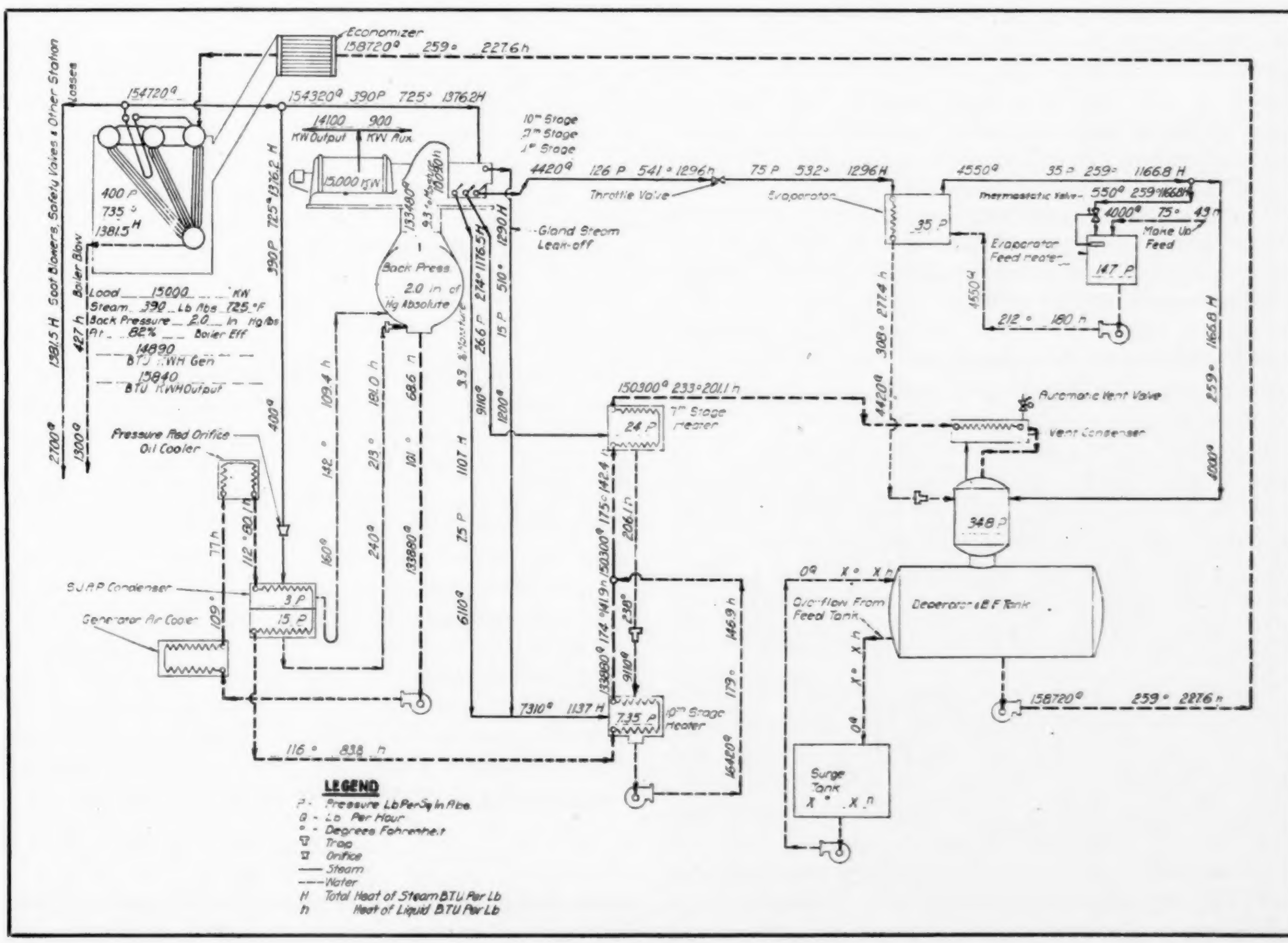



**Fig. 5—Full load heat balance.**

steel panels, four of which are provided for instruments and three for relays. The auxiliary control board is likewise of the vertical type but with slate panels arranged for d.c. distribution, storage battery, voltage regulator, totalizing graphic wattmeter, with provision for future unit No. 2. A separate field switch panel is provided for unit No. 1.

All power and control wiring inside the station, except generator leads, is varnished-cambric lead-covered cable, in fibre conduit where concrete enclosed and in steel conduit where exposed.

Voltage regulator is G-E Company type FTA latest design.

Station auxiliary equipment is supplied by two auxiliary transformers each rated at 2000 kva., 12/2.4 kv., 3-phase, oil-insulated, self-cooled type. One is tapped off the main unit leads between generator and oil circuit breakers and feeds two 2300-volt bus sections through a bus tie oil circuit breaker; the other is fed from the 12 kv. switchyard.

Transformers for small motors consist of two 3-phase 2400/220 volt banks, each made up of three 75 kva., single-phase, oil insulated, self-cooled transformers; a single spare transformer unit is provided for the six working units.

Station and yard lighting is fed from a bank comprising three 25-kva. single-phase 2400/120 volt oil-insulated, self-cooled transformers located in the auxiliary bay. Two of these feed the normal lighting circuits and the third is connected to the emergency lighting system. In case of transformer trouble, the emergency lighting circuits will be fed from the station storage battery until such a time as main unit No. 2 is installed, after which connection will be made to an emergency lighting transformer associated with that unit.

The station storage battery is type E-9 with 60 cells, equipped with a 5-kw. trickle-charging set. The battery is used for operation of relays, annunciators, lighting, and for operation of 7 fractional-hp. motors for control of high-pressure steam valves and fan dampers.

No motor-generator sets or separately-driven exciters are provided.

The 2300-volt auxiliary power structure consists of two 2300-volt bus structures of the truck type, each comprising twelve self-contained bus and oil circuit breaker units. Buses for all auxiliary services are in duplicate throughout, with motors which drive duplicate auxiliary equipment fed from separate transformer banks and bus sections.

The 220-volt leads from transformers for small auxiliary motors are connected to a 220-volt distribution switchboard of six panels feeding the various load centers through air circuit breakers. Load centers consist of un-fused knife switches and buses in steel cabinets.

All wiring in station yard for power and lighting is varnished cambric, lead-covered cable in fibre conduit.

Lighting for station building is of usual design with metal reflectors; yard lighting is provided for oil tanks and spray pond.

Grounding comprises connections for generator neutral, general station protection and yard grounding, all designed as ring systems. Station grounding is made of 1 in. x 1/4 in. copper bar in main runs and 1 in. x 1/8 in. bar in branches. Outdoor grounding consists of 500,000 cm. cable for main line and 250,000 cm. for branches; the main outdoor grounding bus is connected by special terminals to a number of 2 in. dia. galvanized steel pipes driven not less than 10 ft. into the earth. Fuel oil tanks, water tank and concrete chimney are all grounded to the yard system.

The 12-kv. switchyard is of "open" design, with one bay for unit No. 1, one bay for standby auxiliary power transformer, and two bays for 12-kv. ties to Phoenix City substation; the ties consist of a total of four feeders tied together in pairs. The yard is of double bus design with oil circuit breakers on both buses.

The Central Arizona station was designed by the Engineering Department of The Electric Bond and Share Company and constructed by The Phoenix Utility Company for the Central Arizona Light and Power Company.

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**The Mercon Regulator Company** announces extensions to its line of flow controllers. The company has formerly manufactured constant flow regulators, flow limiting regulators, and proportioning regulators for the more general applications involving fluid mixing problems. The new line is broadened to include regulators for maintaining proportional flow of liquids where the two liquids do not mix, or, if mixing, may do so at process points remote from the point of desired control.

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**The Coppus Engineering Corporation,** Worcester, Mass., announces the appointment of John B. Foley, Jr., 510 Hills Building, Syracuse, N. Y., as representative in that district. Mr. Foley will have charge of the sales of Coppus blowers and turbines, Heat Killer cooling fans and Coppus-Annis air filters.

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**The General Electric Company** announces the appointment of Louis E. Underwood as manager of the Pittsfield, Mass., works of the company. Mr. Underwood was formerly managing engineer of the stationary motor engineering department of the General Electric Company at Lynn, Mass., and he is succeeding E. A. Wagner, who has retired.

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**James Cunningham,** president of the Republic Flow Meters Co., Chicago, has been named chairman of the Board of Armour Institute of Technology.

**Here are the fundamentals of combustion calculations, simply expressed and explained. A clear understanding of these fundamentals will greatly facilitate the use of combustion formulas. The author works out calculations for bituminous coal, oil and gas, step by step, using a method that can be applied to any fuel of which the analysis is known . . . . This article, in conjunction with the author's contribution in the July issue, "Derivation and Use of Common Formulas Used in Combustion Calculation", and several articles scheduled for subsequent issues, will constitute a series of exceptional educational and reference value.**

# Fuel Performance Calculations

By P. B. PLACE, Engineer,

Combustion Engineering Corporation

New York

IF the analysis of a fuel is known, its combustion performance may be calculated. Slagging properties and incomplete combustion losses must be estimated from previous experience with similar fuels but such characteristics as the amount of air required for combustion and the amount and analysis of the resulting products of combustion may be readily determined. These characteristics, calculated for various conditions of excess air, may be assembled in a single combustion performance chart that is very useful in comparing different fuels and in checking test performance.

There are several methods of calculating these values. Some of the methods are fundamental and others are empirical short cuts applicable only to special fuels or special conditions. All of the methods are based on the fundamental relationships expressed in the chemical equations for the oxidation of elementary fuels. The elementary fuels with which we are concerned in commercial combustion are carbon, hydrogen, and sulphur named in the order of their importance. The combustible matter of all commercial fuels may be expressed in units of these three elements and the combustion characteristics of the fuel calculated from the combustion equations of these elementary fuels.

The chemical equations expressing the complete combustion of carbon, hydrogen and sulphur are as follows. For the present we need not be concerned about the incomplete combustion of carbon to carbon monoxide or the formation of sulphur trioxide from sulphur.

1. Carbon to carbon dioxide
   $(1)\ C + (1)\ O_2 = (1)\ CO_2$
2. Hydrogen to water vapor
   $2\ H_2 + (1)\ O_2 = 2\ H_2O$
3. Sulphur to sulphur dioxide
   $(1)\ S + (1)\ O_2 = (1)\ SO_2$

These equations are the basis for all combustion calculations and express relationships that should be thoroughly understood by all combustion engineers.

The letters in the equations together with their numerical subscripts represent units of the reacting substances and are termed molecules. Thus C represents one molecule of carbon, $O_2$ represents one molecule of oxygen (made up of two atoms of oxygen) and $CO_2$ represents one molecule of carbon dioxide (made up of an atom of carbon and two atoms of oxygen).

Each molecule has a numerical value that represents its relative weight or molecular weight. This molecular weight is the sum of the atomic weights of the atoms composing the molecule. Thus carbon (C) has a molecular weight of 12, oxygen ($O_2$) has a molecular weight of $2 \times 16 = 32$, and carbon dioxide has a molecular weight of $12 + (2 \times 16) = 44$. It should be understood that these molecular weights are only relative values and may be expressed in any units. Table 1 gives the molecular weights of substances involved in combustion calculations.

It has been established by experiment that a molecular weight of any substance in the gaseous state and under the same conditions of temperature and pressure will occupy the same volume. This law is very significant. The volume will of course vary numerically for different units of weight and volume and for different conditions of temperature and pressure. For combustion calculations the pound and the cubic foot are the units commonly used and unless otherwise stated, the temperature

and pressure are understood to be standard at 32 fahr. (492 abs.) and atmospheric pressure. Thus a molecular weight (32) of oxygen in pounds at 32 fahr. and atmospheric pressure will have the same volume as a molecular weight (44) in pounds of carbon dioxide under the same conditions. This volume is 359 cu. ft.

TABLE 1

*Molecular Weights and Formulas of Substances Involved in Combustion Calculations*

| | Substance | Formula | Molecular Weight | Atomic Weight | Number of Atoms per molecule |
|---|---|---|---|---|---|
| 1. | Carbon ........ | C | 12 | 12 | 1 |
| 2. | Hydrogen ...... | $H_2$ | 2 | 1 | 2 |
| 3. | Sulphur ....... | S | 32 | 32 | 1 |
| 4. | Oxygen ....... | $O_2$ | 32 | 16 | 2 |
| 5. | Nitrogen ...... | $N_2$ | 28 | 14 | 2 |
| 6. | Carbon dioxide.. | $CO_2$ | 44 | .. | 3 |
| 7. | Carbon monoxide | CO | 28 | .. | 2 |
| 8. | Water ......... | $H_2O$ | 18 | .. | 3 |
| 9. | Sulphur dioxide. | $SO_2$ | 64 | .. | 3 |
| 10. | Methane ....... | $CH_4$ | 16 | .. | 5 |
| 11. | Ethane ........ | $C_2H_6$ | 30 | .. | 8 |

A molecular weight expressed in pounds is called a pound mol or simply a "mol" and the volume that it occupies is called a molal volume. This molal volume varies with changes in temperature and pressure according to the well known gas laws, and may be corrected to any desired conditions. Volume is directly proportional to the absolute temperature (460 + t° F.) and inversely proportional to the absolute pressure. Since combustion processes in steam boiler furnaces take place at practically constant atmospheric pressure, pressure corrections are seldom necessary. The change in the molal volume due to temperature (at constant atmospheric pressure) is shown in Fig. 1. For example the volume at 32 fahr. is 359 cu. ft. and at 70 fahr. the volume is

$$359 \times \frac{(460 + 70)}{(460 + 32)} = 386.7 \text{ cu. ft.}$$

Returning now to the combustion equations and applying these conceptions we find that we can write each equation in several ways as follows:

1. (a) (1) C + (1) $O_2$ = (1) $CO_2$
   (b) 1 mol C + 1 mol $O_2$ = 1 mol $CO_2$
   (c) 12 lb. C + 32 lb. $O_2$ = 44 lb. $CO_2$
   (d) 1 lb. C + 32 ÷ 12 lb. $O_2$ = 44 ÷ 12 lb. $CO_2$
   (e) 359 cu. ft. C + 359 cu. ft. $O_2$ = 359 cu. ft. $CO_2$
   (f) 1 vol. C + 1 vol. $O_2$ = 1 vol. $CO_2$

2. (a) 2 $H_2$ + (1) $O_2$ = 2 $H_2O$
   (b) 2 mol $H_2$ + 1 mol $O_2$ = 2 mol $H_2O$
   (c) 4 lb. $H_2$ + 32 lb. $O_2$ = 36 lb. $H_2O$
   (d) 1 lb. $H_2$ + 32 ÷ 4 lb. $O_2$ = 36 ÷ 4 lb. $H_2O$
   (e) 718 cu. ft. $H_2$ + 359 cu. ft. $O_2$ = 718 cu. ft. $H_2O$
   (f) 2 vol. $H_2$ + 1 vol. $O_2$ = 2 vol. $H_2O$

3. (a) (1) S + (1) $O_2$ = (1) $SO_2$
   (b) 1 mol S + 1 mol $O_2$ = 1 mol $SO_2$
   (c) 32 lb. S + 32 lb. $O_2$ = 64 lb. $SO_2$
   (d) 1 lb. S + 32 ÷ 32 lb. $O_2$ = 64 ÷ 32 lb. $SO_2$
   (e) 359 cu. ft. S + 359 cu. ft. $O_2$ = 359 cu. ft. $SO_2$
   (f) 1 vol. S + 1 vol. $O_2$ = 1 vol. $SO_2$

It will be noticed how each equation balances. There are the same number of atoms of each element and the same weight of reacting substances on each side of the equality sign but not necessarily the same number of molecules, mols or volumes. Thus one molecule of carbon plus one molecule of oxygen gives only one molecule of carbon dioxide and two mols of hydrogen plus one mol of oxygen gives only two mols of water vapor.

It will be evident from a consideration of the mol

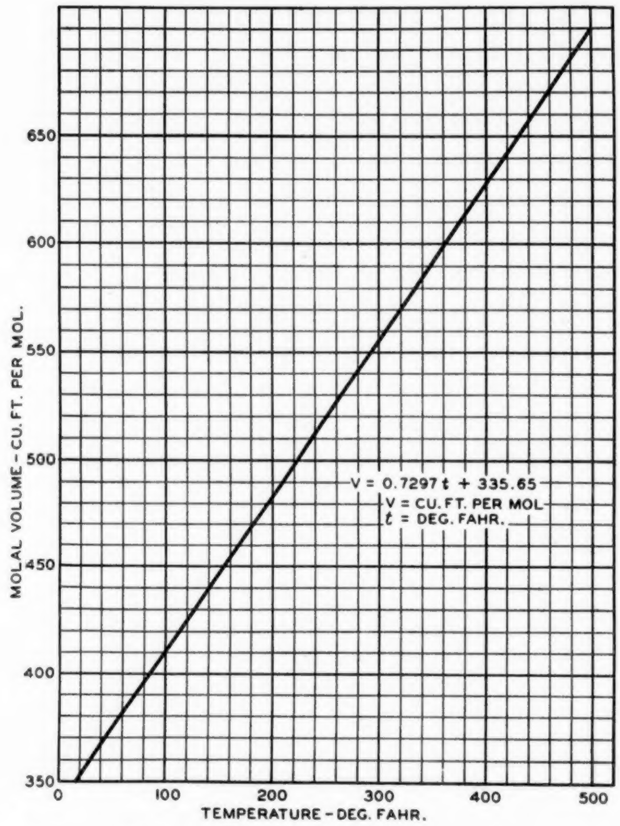



**Fig. 1—Molal volume vs. temperature.**

—volume relationship that per cent by volume is numerically the same as per cent by mol. For example, if we have a mixture of 1/3 of a mol each of oxygen, hydrogen and carbon dioxide we will have 1 mol of the mixture, and the molal volume of this mixture will be 359 cu. ft. under standard conditions. Since each mol of oxygen, hydrogen and carbon dioxide also represents 359 cu. ft. it is evident that the mixture contains 33 1/3 per cent by volume of each substance and also 33 1/3 per cent by mol of each substance.

Since a mol represents a definite weight as well as a definite volume, it serves as a means of calculating analyses by weight into analyses by volume and vice versa. For example, air has a volume analysis of 20.9 per cent of oxygen and 79.1 per cent of nitrogen. Since per cent by volume is per cent by mol, we have in one mol of air, 0.209 mol of oxygen and 0.791 mol of nitrogen. The weights of oxygen and nitrogen corresponding to these mol fractions are 0.209 × 32 = 6.688 and 0.791 × 28 = 22.148 respectively. The total weight therefore of one mol of air or in other words the molecular weight of air is equal to the sum of the weights of the mol fractions or 6.688 + 22.148 = 28.84. The per cent by weight of oxygen in air is then 6.688 ÷ 28.84 × 100 = 23.19 and the per cent by weight of nitrogen in air is similarly 22.148 ÷ 28.84 × 100 = 76.81. Furthermore since the molecular weight of air is 28.84, a mol of air will weigh 28.84 lb. and since a mol is equivalent to 359 cu. ft. the density of air under standard conditions is 28.84 ÷ 359 = 0.0808 lb. per cu. ft. The density of any gas at any temperature is found by dividing the

molecular weight of the gas by the molal volume at that temperature (Fig. 1).

As a second example let us calculate the analysis by weight of gas of the following composition.

| | |
|---|---|
| Methane ($CH_4$) | 20 per cent by volume. |
| Carbon dioxide ($CO_2$) | 20 per cent by volume. |
| Carbon monoxide ($CO$) | 20 per cent by volume. |
| Hydrogen ($H_2$) | 20 per cent by volume. |
| Nitrogen ($N_2$) | 20 per cent by volume. |

The weight analysis may be calculated (1) in terms of the original constituents or (2) in terms of the elementary fuels carbon and hydrogen and the elementary inerts oxygen and nitrogen.

(1) Calculation to analysis by weight in terms of original constituents.

| Constituent | Volume fraction per volume of mixture | Mol per mol of mixture | | Molecular weight of constituent | | Lb. per mol of mixture | | Molecular weight of mixture | | | | Per cent by weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CH_4$ | 0.20 | 0.20 | × | 16 | = | 3.2 | ÷ | 23.6 | × | 100 | = | 13.57 |
| $CO$ | 0.20 | 0.20 | × | 28 | = | 5.6 | ÷ | 23.6 | × | 100 | = | 23.73 |
| $CO_2$ | 0.20 | 0.20 | × | 44 | = | 8.8 | ÷ | 23.6 | × | 100 | = | 37.27 |
| $H_2$ | 0.20 | 0.20 | × | 2 | = | 0.4 | ÷ | 23.6 | × | 100 | = | 1.70 |
| $N_2$ | 0.20 | 0.20 | × | 28 | = | 5.6 | ÷ | 23.6 | × | 100 | = | 23.73 |
| | | 1.00 mol of mixture | | | = | 23.6 lb. | | | | | | 100.00 |

(2) Calculation to analysis by weight in terms of elementary fuels and inerts.

| Constituent | Mol per mol of mixture | Mols per mol of mixture: Carbon C | Hydrogen $H_2$ | Oxygen $O_2$ | Nitrogen $N_2$ |
|---|---|---|---|---|---|
| $CH_4$ | 0.20 | 0.20 | 0.40 | ... | ... |
| $CO$ | 0.20 | 0.20 | ... | 0.10 | ... |
| $CO_2$ | 0.20 | 0.20 | ... | 0.20 | ... |
| $H_2$ | 0.20 | ... | 0.20 | ... | ... |
| $N_2$ | 0.20 | ... | ... | ... | 0.20 |
| | 1.00 | 0.60 | 0.60 | 0.30 | 0.20 |

| Elementary fuel or inert | Mol per mol of mixture | | Molecular weight | | Lb. per mol of mixture | | Molecular weight of mixture | | | | Per cent by weight |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C | 0.60 | × | 12 | = | 7.2 | ÷ | 23.6 | × | 100 | = | 30.51 |
| $H_2$ | 0.60 | × | 2 | = | 1.2 | ÷ | 23.6 | × | 100 | = | 5.09 |
| $O_2$ | 0.30 | × | 32 | = | 9.6 | ÷ | 23.6 | × | 100 | = | 40.66 |
| $N_2$ | 0.20 | × | 28 | = | 5.6 | ÷ | 23.6 | × | 100 | = | 23.74 |
| | 1 Mol of mixture | | | = | 23.6 lb. | | | | | | 100.00 |

The first half of the calculations under (2) may be called a molecular analysis and is an important step in combustion calculations. Each constituent in the fuel analysis is split up into individual mols of the elementary fuels and elementary inerts such as C, $H_2$, S, $O_2$, $N_2$, etc. This can be done by inspection. In the given example, methane ($CH_4$) is made up of a mol of carbon and two mols of hydrogen (each mol of hydrogen consisting of two atoms of hydrogen) and therefore if we have 0.20 of a mol of methane we have 0.20 of a mol of carbon and $2 \times 0.20 = 0.40$ of a mol of hydrogen. Similarly carbon monoxide (CO) is made up of a mol of carbon and a half a mol of oxygen (each mol of oxygen consisting of two atoms of oxygen) and if we have 0.20 of a mol of carbon monoxide we have 0.20 of a mol of carbon and $0.20 \div 2 = 0.10$ of a mol of oxygen. Adding the mols of individual elements we find that in one mol of the fuel we have 0.60 mol of carbon, 0.60 mol of hydrogen, 0.30 mol of oxygen and 0.20 mol of nitrogen. The sum of these, 1.70, has no significance and is not involved in the calculations. Proceeding as in (1) and multiplying each mol fraction by its molecular weight, gives the lb. of each element per mol of mixture. The sum of these weight fractions gives the total weight of molecular weight of the mixture and the per cent by weight of each constituent is readily calculated in the usual manner.

TABLE 2

*Analysis of Three Typical Fuels*

| | | |
|---|---|---|
| 1. Solid—Bituminous coal | | |
| Moisture | 3.0 | per cent by weight. |
| Carbon | 75.0 | per cent by weight. |
| Hydrogen | 4.8 | per cent by weight. |
| Sulphur | 1.0 | per cent by weight. |
| Nitrogen | 1.2 | per cent by weight. |
| Oxygen | 8.5 | per cent by weight. |
| Ash | 6.5 | per cent by weight. |
| | 100.0 | |
| 2. Liquid—Fuel oil | | |
| Carbon | 87.0 | per cent by weight. |
| Hydrogen | 11.0 | per cent by weight. |
| Nitrogen | 0.7 | per cent by weight. |
| Sulphur | 1.1 | per cent by weight. |
| Water | 0.2 | per cent by weight. |
| | 100.0 | |
| 3. Gaseous—Natural gas | | |
| Methane | 74.0 | per cent by volume. |
| Ethane | 15.0 | per cent by volume. |
| Carbon dioxide | 5.0 | per cent by volume. |
| Nitrogen | 6.0 | per cent by volume. |
| | 100.0 | |

Although the reverse process of calculating per cent by volume from per cent by weight is seldom necessary, the procedure is quite simple. The complete analysis of the fuel is necessary and for solid fuels having an ash of unknown molecular weight, the change can only be made on an ash-free basis. The following example is given to illustrate the principle of the reverse calculation. Instead of a basis of one volume or one mol, it is convenient to use 100 lb. of the mixture as the basis for calculation.

Given a gas mixture of the following composition

| | |
|---|---|
| Carbon dioxide ($CO_2$) | 20 per cent by weight. |
| Carbon monoxide ($CO$) | 20 per cent by weight. |
| Oxygen ($O_2$) | 20 per cent by weight. |
| Hydrogen ($H_2$) | 20 per cent by weight. |
| Nitrogen ($N_2$) | 20 per cent by weight. |

| Constituent | Lb. per 100 lb. of mixture | | Molecular weight of constituent | | Mol per 100 lb. of mixture | | Total mol per 100 lb. of mixture | | | | Per cent by mol or by volume |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ | 20 | ÷ | 44 | = | 0.455 | ÷ | 12.508 | × | 100 | = | 3.65 |
| $CO$ | 20 | ÷ | 28 | = | 0.714 | ÷ | 12.508 | × | 100 | = | 5.72 |
| $O_2$ | 20 | ÷ | 32 | = | 0.625 | ÷ | 12.508 | × | 100 | = | 5.00 |
| $H_2$ | 20 | ÷ | 2 | = | 10.000 | ÷ | 12.508 | × | 100 | = | 79.91 |
| $N_2$ | 20 | ÷ | 28 | = | 0.714 | ÷ | 12.508 | × | 100 | = | 5.72 |
| | 100 lb. of mixture | | | = | 12.508 mol | | | | | | 100.00 |
| | 7.99 lb. | | | = | 1.0 mol | | | | | | |

The molecular weight of mixture $= 7.99$
The density of mixture at 32 fahr. $= 7.99 \div 359 = 0.0222$ lb. per cu. ft.
Specific volume at 32 fahr. $= 359 \div 7.99 = 44.95$ cu. ft. per lb.

In Fig. 2, the pounds per mol of a mixture is plotted against per cent by volume of the constituents of the mixture. To find the molecular weight from the volume analysis the weight of the individual constituents are taken from the chart and added together. Thus for air containing 20.9 per cent by volume of oxygen and 79.1 per cent by volume

of nitrogen, we find the weights of oxygen and nitrogen per mol of mixture are 6.6 and 22.2 lb. respectively. The sum of these is 28.8 which value is the molecular weight of air.

TABLE 3

*Calculations for Fuel Performance of Solid Fuels*

Fuel—Bituminous coal.
Excess Air—10 per cent.
Basis of Calculation—100 lb. fuel.

*Analysis of Fuel*

| | Per cent by weight | Mol per 100 lb. fuel | Mols per 100 lb. of fuel: Carbon C | Hydrogen $H_2$ | Sulphur S | Oxygen $O_2$ | Nitrogen $N_2$ |
|---|---|---|---|---|---|---|---|
| Moisture, $H_2O$ | 3.0 | 0.167 | .... | 0.167 | .... | 0.083 | .... |
| Carbon, C | 75.0 | 6.250 | 6.250 | .... | .... | .... | .... |
| Hydrogen, $H_2$ | 4.8 | 2.400 | .... | 2.400 | .... | .... | .... |
| Sulphur, S | 1.0 | 0.031 | .... | .... | 0.031 | .... | .... |
| Nitrogen, $N_2$ | 1.2 | 0.043 | .... | .... | .... | .... | 0.043 |
| Oxygen, $O_2$ | 8.5 | 0.266 | .... | .... | .... | 0.266 | .... |
| Ash | 6.5 | .... | .... | .... | .... | .... | .... |
| | 100.0 | Total | 6.250 | 2.567 | 0.031 | 0.349 | 0.043 |

| | Mols per 100 lb. of fuel: C | $H_2$ | S | $O_2$ | $N_2$ | Total |
|---|---|---|---|---|---|---|
| 1. Total oxygen required | 6.250 | 1.283 | 0.031 | .... | .... | 7.564 |
| 2. Oxygen in the fuel.. | .... | .... | .... | 0.349 | .... | 0.349 |
| 3. Oxygen in required air | 6.250 | 0.934 | 0.031 | .... | .... | 7.215 |
| 4. Excess oxygen in gases | 0.625 | 0.093 | 0.003 | .... | .... | 0.721 |
| 5. Total oxygen supplied by air .............. | 6.875 | 1.027 | 0.034 | .... | .... | 7.936 |
| 6. Total air supplied.... | 32.895 | 4.914 | 0.162 | .... | .... | 37.971 |
| 7. Nitrogen in air supplied .............. | 26.020 | 3.887 | 0.128 | .... | .... | 30.033 |
| 8. Nitrogen in the fuel. | .... | .... | .... | .... | 0.043 | 0.043 |
| 9. Total nitrogen in gases .............. | 26.020 | 3.887 | 0.128 | .... | 0.043 | 30.078 |
| 10. Carbon dioxide in gases .............. | 6.250 | .... | .... | .... | .... | 6.250 |
| 11. Water vapor in gases | .... | 2.567 | .... | .... | .... | 2.567 |
| 12. Sulphur dioxide in gases .............. | .... | .... | 0.031 | .... | .... | 0.031 |
| 13. Total dry gases...... (Totals of items 4, 9, 10 and 12) | 32.895 | 3.980 | 0.162 | .... | 0.043 | 37.080 |
| 14. Total wet gases...... (Totals of items 4, 9, 10, 11 and 12) | 32.895 | 6.547 | 0.162 | .... | 0.043 | 39.647 |

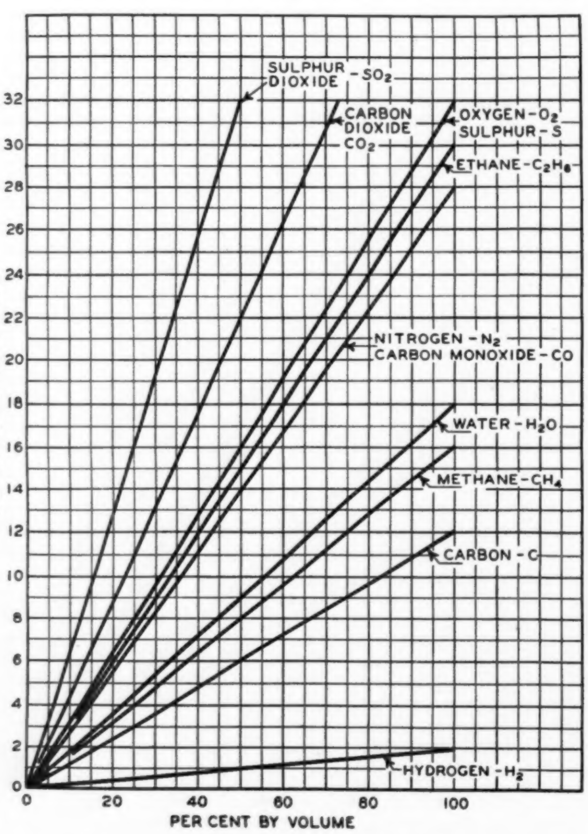



**Fig. 2—Pounds per mol vs. per cent by volume.**

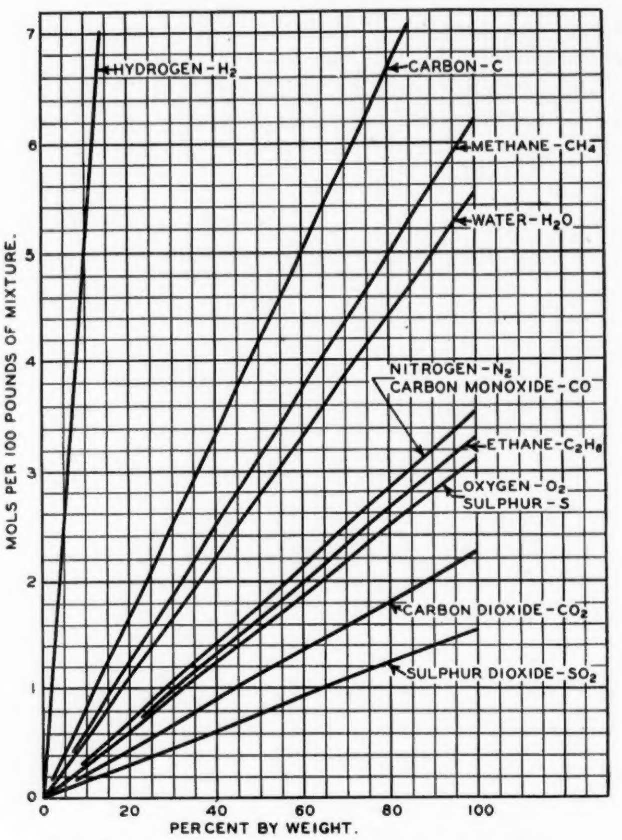



**Fig. 3—Mols per 100 lb. vs. per cent by weight.**

*Analysis of Products of Combustion*

| | | Dry gases | Wet gases |
|---|---|---|---|
| Per cent by vol. | $CO_2$ | $\dfrac{6.250 \times 100}{37.080} = 16.86$ | $\dfrac{6.250 \times 100}{39.647} = 15.77$ |
| Per cent by vol. | $SO_2$ | $\dfrac{0.031 \times 100}{37.080} = 0.08$ | $\dfrac{0.031 \times 100}{39.647} = 0.08$ |
| Per cent by vol. | $O_2$ | $\dfrac{0.721 \times 100}{37.080} = 1.94$ | $\dfrac{0.721 \times 100}{39.647} = 1.82$ |
| Per cent by vol. | $N_2$ | $\dfrac{30.078 \times 100}{37.080} = 81.12$ | $\dfrac{30.078 \times 100}{39.647} = 75.86$ |
| Per cent by vol. | $H_2O$ | ............ | $\dfrac{2.567 \times 100}{39.647} = 6.47$ |
| | | 100.00 | 100.00 |

*Molecular Weight of Products of Combustion*

| | Dry gases | Wet gases |
|---|---|---|
| $CO_2$ ............. | $0.1686 \times 44 = 7.42$ | $0.1577 \times 44 = 6.94$ |
| $SO_2$ ............. | $0.0008 \times 64 = 0.05$ | $0.0008 \times 64 = 0.05$ |
| $O_2$ ............. | $0.0194 \times 32 = 0.62$ | $0.0182 \times 32 = 0.58$ |
| $N_2$ ............. | $0.8112 \times 28 = 22.71$ | $0.7586 \times 28 = 21.24$ |
| $H_2O$ ............. | .................... | $0.0647 \times 18 = 1.16$ |
| | 1.0 mol = 30.80 | 1.0 mol = 29.96 |

| | Mol per lb. of fuel (a) | Molecular weight (b) | Lb. per lb. of fuel (a×b) | Temp. deg. fahr. (assumed) | Molal volume (c) (fig. 1) | Cu. ft. per lb. fuel (a×c) |
|---|---|---|---|---|---|---|
| Dry gases .... | 0.371 | 30.80 | 11.43 | 300 | 555 | 205.9 |
| Water vapor.... | 0.026 | 18.00 | 0.46 | 300 | 555 | 14.4 |
| Wet gases .... | 0.397 | 29.96 | 11.89 | 300 | 555 | 220.3 |
| Air .......... | 0.380 | 28.84 | 10.95 | 70 | 388 | 147.4 |

In Fig. 3, the mols of individual constituents per 100 lb. of mixture are plotted against per cent by weight of the constituents. The two charts are useful in calculations similar to the above examples.

In Table 2 the analyses of three different types of fuel are given. The coal and fuel oil analyses are on a weight basis and the natural gas analysis is on a volume basis as is customary. The fuel per-

formance of each of these three fuels will be determined and the method of calculation explained in detail.

The calculations are assembled in standardized form in Tables 3, 5 and 7 and 4, 6 and 8. Tables 3, 5 and 7 give the complete calculations for one condition of excess air, 10 per cent in the example shown.

TABLE 4

*Combustion Characteristics—Bituminous Coal*

| Excess air—per cent.. | 0 | 20 | 40 | 60 | 80 | 100 |
|---|---|---|---|---|---|---|
| Per cent $CO_2$ in dry gases | 18.59 | 15.42 | 13.18 | 11.50 | 10.21 | 9.17 |
| Per cent $SO_2$ in dry gases | 0.09 | 0.07 | 0.06 | 0.06 | 0.05 | 0.04 |
| Per cent $O_2$ in dry gases. | 0.00 | 3.56 | 6.08 | 7.97 | 9.42 | 10.59 |
| Per cent $N_2$ in dry gases | 81.32 | 80.95 | 80.68 | 80.47 | 80.32 | 80.20 |
| Mol wt. of dry gases.... | 31.00 | 30.64 | 30.37 | 30.18 | 30.03 | 29.91 |
| Mol wt. of wet gases.... | 30.08 | 29.89 | 29.74 | 29.63 | 29.56 | 29.47 |
| Dry gases—lb. per lb. fuel | 10.42 | 12.42 | 14.41 | 16.40 | 18.39 | 20.38 |
| Wet gases—lb. per lb. fuel | 10.88 | 12.88 | 14.87 | 16.86 | 18.85 | 20.84 |
| Air—lb. per lb. fuel..... | 9.96 | 11.95 | 13.94 | 15.93 | 17.92 | 19.91 |
| Wet gases—cu. ft. per lb.* | 129.8 | 154.7 | 179.5 | 204.3 | 228.9 | 253.9 |
| Air—cu. ft. per lb. fuel* | 124.0 | 148.8 | 173.5 | 198.3 | 223.1 | 247.8 |

* Under standard conditions of temperature and pressure.

Tables 4, 6 and 8 give the assembled characteristics for 0, 20, 40, 60, 80 and 100 per cent excess air. The data of Tables 4, 6 and 8 are plotted in the combustion performance charts, Fig. 4, 5 and 6.

Tables 3, 5, and 7 are practically identical in form. The only differences are (1) the basis of calculation, which is conveniently 100 lb. for fuels analysed on a weight basis, and one volume or one mol for fuels analysed on a volume basis, and (2) the first step in the determination of the molecular analysis. To determine the number of mols per 100 lb. of fuel, the weight fraction of each constituent is divided by the molecular weight of the constituent. To determine the mols per volume or the mols per mol of fuel, no calculation is required because per cent by volume is numerically the same as mols per mol.

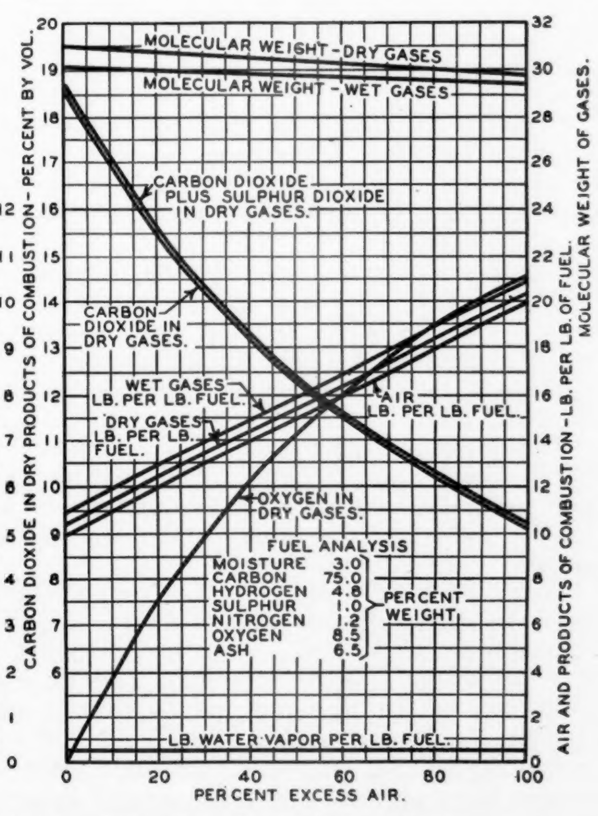



**Fig. 4—Combustion characteristics—bituminous coal.**

In the second half of the calculations given in Tables 3, 5 and 7 the air required for the combustion of each constituent and the composition and amount of the products of combustion are developed in such sequence that every item involved in the calculations is accounted for and readily available for checking or for conversion to pounds or cubic feet. Errors are reduced to a minimum and doubts eliminated concerning fuels containing large amounts of carbon dioxide, sulphur, nitrogen and other constituents that may confuse the calculation of the amount and analysis of the products of combustion.

TABLE 5

*Calculations for Fuel Performance of Liquid Fuels*

Fuel—Fuel oil.
Excess air—10 per cent.
Basis of calculation—100 lb. of fuel.

*Analysis of Fuel*

| | Per cent by weight | Mol per 100 lb. fuel | Mols per 100 lb. of fuel: Carbon C | Hydrogen $H_2$ | Sulphur S | Oxygen $O_2$ | Nitrogen $N_2$ |
|---|---|---|---|---|---|---|---|
| Carbon, C | 87.0 | 7.250 | 7.250 | .... | .... | .... | .... |
| Hydrogen, $H_2$ | 11.0 | 5.500 | .... | 5.500 | .... | .... | .... |
| Nitrogen, $N_2$ | 0.7 | 0.025 | .... | .... | .... | .... | 0.025 |
| Sulphur, S | 1.1 | 0.034 | .... | .... | 0.034 | .... | .... |
| Water, $H_2O$ | 0.2 | 0.011 | .... | 0.011 | .... | 0.005 | .... |
| | 100.0 | Total | 7.250 | 5.511 | 0.034 | 0.005 | 0.025 |

| | Mols per 100 lb. of fuel: C | $H_2$ | S | $O_2$ | $N_2$ | Total |
|---|---|---|---|---|---|---|
| 1. Total oxygen required | 7.250 | 2.755 | 0.034 | .... | .... | 10.039 |
| 2. Oxygen in the fuel.. | .... | .... | .... | 0.005 | .... | 0.005 |
| 3. Oxygen in required air | 7.250 | 2.750 | 0.034 | .... | .... | 10.034 |
| 4. Excess oxygen in gases | 0.725 | 0.275 | 0.003 | .... | .... | 1.003 |
| 5. Total oxygen supplied by air ............ | 7.975 | 3.025 | 0.037 | .... | .... | 11.037 |
| 6. Total air supplied.... | 38.157 | 14.473 | 0.177 | .... | .... | 52.807 |
| 7. Nitrogen in air supplied ............ | 30.182 | 11.448 | 0.140 | .... | .... | 41.770 |
| 8. Nitrogen in the fuel. | .... | .... | .... | .... | 0.025 | 0.025 |
| 9. Total nitrogen in gases ............ | 30.182 | 11.448 | 0.140 | .... | 0.025 | 41.795 |
| 10. Carbon dioxide in gases ............ | 7.250 | .... | .... | .... | .... | 7.250 |
| 11. Water vapor in gases | .... | 5.511 | .... | .... | .... | 5.511 |
| 12. Sulphur dioxide in gases ............ | .... | .... | 0.034 | .... | .... | 0.034 |
| 13. Total dry gases...... (Total of items 4, 9, 10 and 12) | 38.157 | 11.723 | 0.177 | .... | 0.025 | 50.082 |
| 14. Total wet gases...... (Total of items 4, 9, 10, 11 and 12) | 38.157 | 17.234 | 0.177 | .... | 0.025 | 55.593 |

*Analysis of Products of Combustion*

| | | Dry gases | Wet gases |
|---|---|---|---|
| Per cent by vol. | $CO_2$ | $\frac{7.250 \times 100}{50.082} = 14.48$ | $\frac{7.250 \times 100}{55.593} = 13.04$ |
| Per cent by vol. | $SO_2$ | $\frac{0.034 \times 100}{50.082} = 0.07$ | $\frac{0.034 \times 100}{55.593} = .06$ |
| Per cent by vol. | $O_2$ | $\frac{1.003 \times 100}{50.082} = 2.00$ | $\frac{1.003 \times 100}{55.593} = 1.80$ |
| Per cent by vol. | $N_2$ | $\frac{41.795 \times 100}{50.082} = 83.45$ | $\frac{41.795 \times 100}{55.593} = 75.19$ |
| Per cent by vol. | $H_2O$ | ............ | $\frac{5.511 \times 100}{55.593} = 9.91$ |
| | | 100.00 | 100.00 |

*Molecular Weight of Products of Combustion*

| | Dry gases | Wet gases |
|---|---|---|
| $CO_2$ ............ | $0.1448 \times 44 = 6.37$ | $.1304 \times 44 = 5.74$ |
| $SO_2$ ............ | $0.0007 \times 64 = 0.04$ | $.0006 \times 64 = .04$ |
| $O_2$ ............ | $0.0200 \times 32 = 0.64$ | $.0180 \times 32 = .58$ |
| $N_2$ ............ | $0.8345 \times 28 = 23.37$ | $.7519 \times 28 = 21.05$ |
| $H_2O$ ............ | .................... | $.0991 \times 18 = 1.78$ |
| | 1.0 mol = 30.42 | 1.0 mol = 29.19 |

| | Mol per lb. of fuel (a) | Molecular weight (b) | Lb. per lb. of fuel (a×b) | Temp. deg. fahr. (assumed) | Molal volume (fig. 1) (c) | Cu. ft. per lb. fuel (a×c) |
|---|---|---|---|---|---|---|
| Dry gases ..... | 0.501 | 30.42 | 15.24 | 500 | 700 | 350.7 |
| Water vapor.... | 0.055 | 18.00 | 0.99 | 500 | 700 | 38.5 |
| Wet gases .... | 0.556 | 29.19 | 16.23 | 500 | 700 | 389.2 |
| Air ........... | 0.528 | 28.84 | 15.23 | 70 | 388 | 204.9 |

Item 1, the total oxygen required, follows directly from the elementary fuel equations. 6.250 mols of carbon require 6.250 mols of oxygen and 2.567 mols of hydrogen require 2.567 ÷ 2 or 1.283 mols of oxygen for complete combustion.

TABLE 6

*Combustion Characteristics—Fuel Oil*

| Excess air—per cent.. | 0 | 20 | 40 | 60 | 80 | 100 |
|---|---|---|---|---|---|---|
| Per cent $CO_2$ in dry gases | 16.01 | 13.20 | 11.24 | 9.78 | 8.66 | 7.77 |
| Per cent $SO_2$ in dry gases | 0.08 | 0.07 | 0.06 | 0.05 | 0.04 | 0.04 |
| Per cent $O_2$ in dry gases | 0.00 | 3.66 | 6.22 | 8.12 | 9.59 | 10.75 |
| Per cent $N_2$ in dry gases. | 83.91 | 83.07 | 82.48 | 82.05 | 81.71 | 81.44 |
| Molecular wt. of dry gases | 30.59 | 30.28 | 30.07 | 29.91 | 29.78 | 29.69 |
| Molecular wt. of wet gases | 29.22 | 29.16 | 29.12 | 29.08 | 29.06 | 29.03 |
| Dry gases—lb. per lb. fuel | 13.86 | 16.62 | 19.39 | 22.16 | 24.93 | 27.70 |
| Wet gases—lb. per lb. fuel | 14.84 | 17.61 | 20.38 | 23.15 | 25.91 | 28.69 |
| Air—lb. per lb. fuel..... | 13.85 | 16.61 | 19.38 | 22.15 | 24.92 | 27.69 |
| Wet gases—cu. ft. per lb.* | 182.3 | 216.8 | 251.2 | 285.8 | 320.1 | 354.8 |
| Air—cu. ft. per lb.*.... | 172.4 | 206.7 | 241.2 | 275.7 | 310.2 | 344.7 |

* Under standard conditions of temperature and pressure.

Since some oxygen is already present in the fuel, item 2, it is subtracted from item 1 to give the amount of oxygen that must be supplied by air, item 3. In the distribution of the oxygen supplied it has been assumed that the oxygen present in the fuel is combined with the hydrogen in the fuel and, therefore, the 0.349 mol of oxygen in Table 3 has been substracted from the 1.283 mols of oxygen required for the combustion of the hydrogen.

Item 4 represents the excess air. In the example given the excess air is taken at 10 per cent. If the excess air is assumed at 30 per cent, item 4 will be 7.215 × 0.30 = 2.165. The sequence of items 2, 3 and 4 is important. Excess air is per cent of the air or oxygen required for combustion and therefore must be calculated from the oxygen to be supplied after the oxygen in the fuel is accounted for.

Item 5 is the total oxygen to be supplied by the air and requires no explanation. Item 6 is calculated from item 5 by dividing by the per cent by volume (per cent by mol) of oxygen in air, namely 20.9. Item 7 is calculated from item 6 by multiplying by the per cent by volume of nitrogen in air namely 79.1. Item 7 is also the difference between items 5 and 6. To this nitrogen must be added the nitrogen present in the fuel because both appear in the products of combustion.

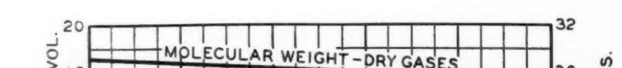



Fig. 5—Combustion characteristics—fuel oil.

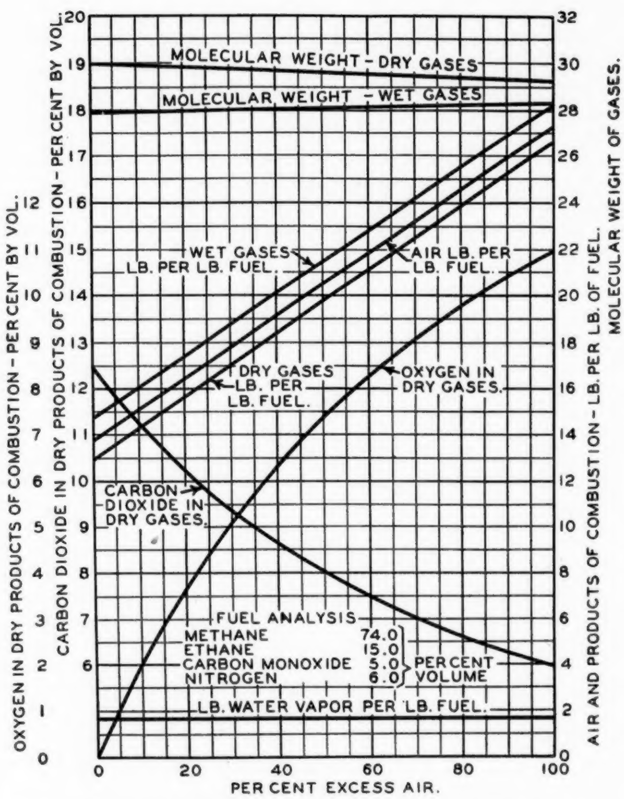



Fig. 6—Combustion characteristics—natural gas.

Items 10, 11 and 12 are based on the molecular analysis and the combustion equation relationships. 6.250 mols of carbon give 6.250 mols of carbon dioxide, 2.567 mols of hydrogen give 2.567 mols of water vapor, etc.

The total dry gases, item 13 is the sum of items 4, 9, 10 and 12. The total wet gases, item 14 is the sum of the dry gases and the water vapor. The water vapor includes both the moisture in the fuel and the water vapor formed by the combustion of the hydrogen.

The analysis of the products of combustion in per cent by volume is found by calculating the per cent by mol as shown. The molecular weight of the dry gases and wet gases is then determined as shown.

The molecular weight of the fuel is required when the basis of calculation is 1 mol, in order to convert the results from mols or lb. per mol of fuel to mols per lb. of fuel. The molecular weight of solid fuels containing ash cannot be determined because the molecular weight of the ash is not a definite quantity but such fuels are calculated to a weight basis and the molecular weight is not required.

All of the items in Tables 3 and 5, that are in terms of mols per lb. of fuel can be quickly converted to lb. per lb. of fuel by multiplying by the proper molecular weight or to cu. ft. per lb. of fuel by multiplying by the proper molal volume. For example the mols of dry gases per lb. of fuel in Table 3 is 0.371 and the molecular weight of the dry gases is 30.80. Therefore the lb. of dry gases per lb. of fuel is $0.371 \times 30.80 = 11.43$. Similarly if the temperature of the air is 70 fahr. and the mols of air per lb. of fuel is 0.380, the molal volume at 70 fahr. is 388 cu. ft. and the volume of air per lb. of fuel is $0.380 \times 388 = 147.4$ cu. ft.

The items in Table 7 are on a basis of a mol rather than a lb. of fuel. The conversion to lb. per lb. of fuel or cu. ft. per lb. of fuel is made as explained above except that it is necessary to divide by the molecular weight of the fuel. For example the mols of dry gases per mol of fuel in Table 7 is 9.70, the molecular weight of the dry gases is 29.88, and the molecular weight of the fuel gas is 20.22. The lb. of dry gas per mol of fuel is then $9.70 \times 29.88 = 289.84$ and the lb. of dry gas per lb. of fuel is $289.84 \div 20.22 = 14.33$. Similarly the cu. ft. of air at 70 fahr. per lb. of fuel is equal to $10.553 \times 388 \div 20.22 = 202.5$.

If the combustion characteristics of gaseous fuels are desired on a cu. ft. of fuel basis, the calculations are equally simple. Instead of dividing by the molecular weight of the fuel we divide by the molal volume at fuel gas temperature. For example in Table 7 the lb. of dry gases per cu. ft. of fuel gas at 70 fahr. is equal to $9.70 \times 29.88 \div 388 = 0.747$, or the cu. ft. of air at 70 fahr. per cu. ft. of fuel gas at 70 fahr. is $10.553 \times 388 \div 388 = 10.553$. At the same temperature the mols per mol data is the same as cu. ft. per cu. ft.

In plotting the data in Figs. 3, 4 and 5 the per cent of $CO_2$ and $SO_2$ have been added together because usually both are determined as $CO_2$ in an Orsat analysis of the gases. All three charts have been plotted on the same scale in order to bring out the differences in the characteristics of the three fuels. The variation in the per cent of $CO_2$ and the amount of air and products of combustion will be noticed. The relative positions of the air, dry gases and wet gases lines are of interest. The solid fuel chart shows the dry gases line between the wet gases and the air, while for the gaseous fuel the air line takes the middle position.

The per cent of oxygen in the dry gases is a much better indicator of the amount of excess air than is the per cent of carbon dioxide except for fuels containing large amounts of nitrogen.

TABLE 7

*Calculations for Fuel Performance of Gaseous Fuels*

**Fuel—Natural gas.**
**Excess air—10 per cent.**
**Basis of calculation—1 volume or 1 mol of fuel.**

*Analysis of Fuel*

| | Per cent by vol. | Mol per mol of fuel | Mols per mol of fuel: Carbon C | Hydrogen $H_2$ | Sulphur S | Oxygen $O_2$ | Nitrogen $N_2$ |
|---|---|---|---|---|---|---|---|
| Methane, $CH_4$ | 74.0 | 0.740 | 0.740 | 1.480 | .... | .... | .... |
| Ethane, $C_2H_6$ | 15.0 | 0.150 | 0.300 | 0.450 | .... | .... | .... |
| Carbon dioxide, $CO_2$ | 5.0 | 0.005 | 0.050 | .... | .... | 0.050 | .... |
| Nitrogen, $N_2$ | 6.0 | 0.006 | .... | .... | .... | .... | 0.060 |
| Total | 100.0 | 1.000 | 1.090 | 1.930 | | 0.050 | 0.060 |

| | Mol per mol of fuel: C | $H_2$ | S | $O_2$ | $N_2$ | Total |
|---|---|---|---|---|---|---|
| 1. Total oxygen required | 1.090 | 0.965 | .... | .... | .... | 2.055 |
| 2. Oxygen in fuel...... | .... | .... | .... | 0.050 | .... | 0.050 |
| 3. Oxygen in required air | 1.090 | 0.915 | .... | .... | .... | 2.005 |
| 4. Excess oxygen in gases | 0.109 | 0.091 | .... | .... | .... | 0.200 |
| 5. Total oxygen supplied by air .............. | 1.199 | 1.006 | .... | .... | .... | 2.205 |
| 6. Total air supplied... | 5.737 | 4.816 | .... | .... | .... | 10.553 |
| 7. Nitrogen in air supplied ............... | 4.538 | 3.809 | .... | .... | .... | 8.347 |
| 8. Nitrogen in the fuel.. | .... | .... | .... | .... | 0.060 | 0.060 |
| 9. Total nitrogen in gases ............... | 4.538 | 3.809 | .... | .... | 0.060 | 8.407 |
| 10. Carbon dioxide in gases ............... | 1.090 | .... | .... | .... | .... | 1.090 |
| 11. Water vapor in gases | .... | 1.930 | .... | .... | .... | 1.930 |
| 12. Sulphur dioxide in gases ............... | .... | .... | .... | .... | .... | .... |
| 13. Total dry gases...... (Total of items 4, 9, 10 and 12) | 5.737 | 3.900 | .... | .... | 0.060 | 9.697 |
| 14. Total wet gases..... (Total of items 4, 9, 10, 11 and 12) | 5.737 | 5.830 | .... | .... | 0.060 | 11.627 |

*Analysis of Products of Combustion*

| | | Dry gases | Wet gases |
|---|---|---|---|
| Per cent by vol. | $CO_2$ | $\frac{1.090 \times 100}{9.697} = 11.24$ | $\frac{1.090 \times 100}{11.627} = 9.37$ |
| Per cent by vol. | $SO_2$ | ............ | ............ |
| Per cent by vol. | $O_2$ | $\frac{0.200 \times 100}{9.697} = 2.07$ | $\frac{0.200 \times 100}{11.627} = 1.72$ |
| Per cent by vol. | $N_2$ | $\frac{8.407 \times 100}{9.697} = 86.69$ | $\frac{8.407 \times 100}{11.627} = 72.31$ |
| Per cent by vol. | $H_2O$ | ............ | $\frac{1.930 \times 100}{11.627} = 16.60$ |
| | | 100.00 | 100.00 |

*Molecular Weight of Products of Combustion*

| | Dry gases | Wet gases |
|---|---|---|
| $CO_2$ ............. | $0.1124 \times 44 = 4.95$ | $0.0937 \times 44 = 4.12$ |
| $SO_2$ ............. | ............ | ............ |
| $O_2$ ............. | $0.0207 \times 32 = 0.66$ | $0.0172 \times 32 = 0.55$ |
| $N_2$ ............. | $0.8669 \times 28 = 24.27$ | $0.7231 \times 28 = 20.25$ |
| $H_2O$ ............. | ............ | $0.1660 \times 18 = 2.99$ |
| | 1.0 mol $= 29.88$ | 1.0 mol $= 27.91$ |

*Molecular Weight of Fuel Gas*

| | |
|---|---|
| $CH_4$ ................. | $0.740 \times 16 = 11.84$ |
| $C_2H_6$ ................. | $0.150 \times 30 = 4.50$ |
| $CO_2$ ................. | $0.050 \times 44 = 2.20$ |
| $N_2$ ................. | $0.060 \times 28 = 1.68$ |
| | 1.0 mol $= 20.22$ |

| | Mol per mol of fuel | Mol per lb. of fuel (a) | Molecular weight (b) | Lb. per lb. of fuel (a×b) | Temp. deg. fahr. (assumed) | Molal volume (fig. 1) (c) | Cu. ft. per lb. of fuel (a×c) |
|---|---|---|---|---|---|---|---|
| Dry gases .... | 9.70 | 0.480 | 29.88 | 14.34 | 400 | 627 | 301.0 |
| Water vapor... | 1.93 | 0.095 | 18.00 | 1.71 | 400 | 627 | 59.5 |
| Wet gases..... | 11.63 | 0.575 | 27.91 | 16.05 | 400 | 627 | 360.5 |
| Air .......... | 10.55 | 0.522 | 28.84 | 15.05 | 240 | 510 | 266.2 |

TABLE 8

*Combustion Characteristics—Natural Gas*

| Excess air—per cent.. | 0 | 20 | 40 | 60 | 80 | 100 |
|---|---|---|---|---|---|---|
| Per cent $CO_2$ in dry gases | 12.47 | 10.23 | 8.67 | 7.52 | 6.64 | 5.95 |
| Per cent $SO_2$ in dry gases | .... | .... | .... | .... | .... | .... |
| Per cent $O_2$ in dry gases | 0.00 | 3.76 | 6.38 | 8.30 | 9.77 | 10.94 |
| Per cent $N_2$ in dry gases | 87.53 | 86.01 | 84.95 | 84.18 | 83.59 | 83.11 |
| Mol. wt. of dry gases.... | 29.99 | 29.79 | 29.64 | 29.54 | 29.45 | 29.39 |
| Mol. wt. of wet gases.... | 27.83 | 27.98 | 28.09 | 28.18 | 28.25 | 28.31 |
| Dry gases—lb. per lb. fuel | 12.96 | 15.70 | 18.43 | 21.17 | 23.91 | 26.65 |
| Wet gases—lb. per lb. fuel | 14.68 | 17.42 | 20.15 | 22.89 | 25.63 | 28.37 |
| Air—lb. per lb. fuel..... | 13.68 | 16.42 | 19.15 | 21.89 | 24.63 | 27.37 |
| Wet gases—cu. ft. per lb. fuel * ................ | 189.4 | 223.5 | 257.5 | 291.6 | 325.7 | 359.8 |
| Air—cu. ft. per lb. fuel * | 170.3 | 204.4 | 238.4 | 272.5 | 306.6 | 340.7 |

* Under standard conditions of temperature and pressure.

It should be understood that the three charts given here cannot be taken as typical of solid, liquid and gaseous fuels without reservation. Each fuel has its own performance chart made from an accurate analysis of the fuel. The variation in

charts for coals will be small but the variations in charts for gaseous fuels may be very great. Even different samples of natural gas may have widely different charts. The variations are largely due to the presence of inerts like $CO_2$ and $N_2$ in the fuel that appear unchanged as diluents in the products of combustion. The variations in hydrogen content of fuels is another factor that shows in the charts in the relative positions of the air and gases lines.

It is evident that the method described is very flexible. Blank calculation sheets can be made in standard form and serve as convenient file and reference records. Although the procedure may appear long and cumbersome at first sight, many of the items can be filled in by inspection and details have been given here that are not necessary to those familiar with the system. Whether used or not, the system should be understood as the relationships expressed are the basis for all combustion formulas.

## New Members on Advisory Committee of New York Power Show

The management of the New York Power Show announces the acceptance of membership on the Advisory Committee by A. D. Bailey, Superintendent of Power Generation, Commonwealth Edison Co., Chicago; V. M. Frost, Public Service Electric & Gas Co., New Jersey; and A. C. Fieldner of the U. S. Bureau of Mines.

The present members of the Advisory Committee, in addition to the above, are: I. E. Moultrop, Edison Electric Illuminating Co., of Boston (Chairman); Homer Addams, past president, American Society of Heating & Ventilating Engineers; N. A. Carle, Manager, Pacific Electric & Manufacturing Co.; Fred Felderman, past president, National Association of Power Engineers; C. F. Hirshfeld, Chief of Research Department, Detroit Edison Company; O. P. Hood, Chief Mechanical Engineer, U. S. Bureau of Mines; Conrad N. Lauer, President, The American Society of Mechanical Engineers; John H. Lawrence, President, Thomas E. Murray, Inc.; Fred R. Low, past president, The American Society of Mechanical Engineers; Glenn Muffly, President, American Society of Refrigerating Engineers; David Moffatt Myers, Consulting Engineer; F. B. Rowley, President, American Society of Heating & Ventilating Engineers; and Charles F. Roth and Fred W. Payne, co-managers of the Exposition.

## Obituary Notice

Robert L. Sheraton, New England representative of the Hagan Corporation, died the morning of September 2nd at his home in Newtonville, Mass., following a short illness.

# Boiler, Stoker and Pulverized Fuel Equipment Sales

***As reported by equipment manufacturers to the Department of Commerce, Bureau of the Census.***

## Boiler Sales

Orders for 327 boilers were placed in July by 72 manufacturers

| | Number | Square feet |
|---|---|---|
| July, 1932 | 327 | 350,745 |
| July, 1931 | 785 | 650,942 |
| January to July (inclusive, 1932) | 1,867 | 1,954,754 |
| Equivalent period, 1931 | 4,376 | 3,992,478 |
| Total, 1931 | 7,508 | 6,327,262 |

NEW ORDERS, BY KIND, PLACED IN JULY, 1931-1932

| | July, 1931 | | July, 1932 | |
|---|---|---|---|---|
| Kind | Number | Square feet | Number | Square feet |
| Stationary: | | | | |
| Water tube | 87 | 297,636 | 43 | 213,318 |
| Horizontal return tubular | 45 | 56,990 | 30 | 38,033 |
| Vertical fire tube | 55 | 19,194 | 30 | 6,659 |
| Locomotive, not railway | 4 | 1,664 | 4 | 4,223 |
| Steel heating | 561 | 246,001 | 209 | 82,100 |
| Oil country | 3 | 2,530 | .... | ...... |
| Self contained portable | 29 | 26,808 | 10 | 6,092 |
| Miscellaneous | 1 | 119 | 1 | 320 |
| Total | 785 | 650,942 | 327 | 350,745 |

## Mechanical Stoker Sales

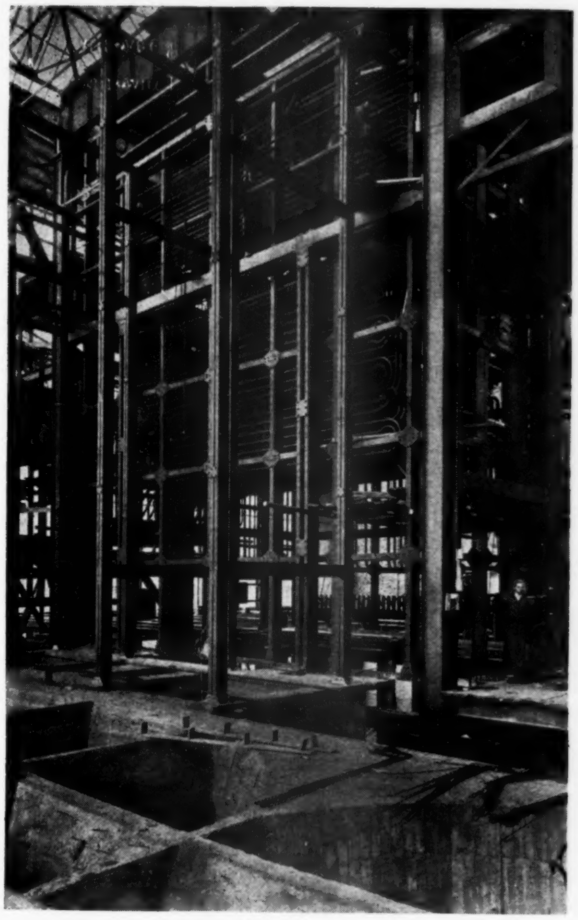
Orders for 114 stokers totaling 25,068 hp. were placed in July by 55 manufacturers

| | Installed under | | | |
|---|---|---|---|---|
| | Fire-tube boilers | | Water-tube boilers | |
| | No. | Horsepower | No. | Horsepower |
| July, 1932 | 70 | 8,605 | 44 | 16,463 |
| July, 1931 | 202 | 25,765 | 51 | 13,627 |
| January to July (inclusive, 1932) | 449 | 59,568 | 229 | 94,279 |
| Equivalent period, 1931 | 831 | 108,159 | 333 | 114,504 |
| Total, 1931 | 1,889 | 252,571 | 574 | 187,507 |

## Pulverized Fuel Equipment Sales

Orders for 7 pulverizers with a total capacity of 18,250 lb. per hr. were placed in July

| | Total Number | No. for new boilers, furnaces and kilns | No. for existing boilers | Total capacity lb. coal per hour for contract | Number | Total sq. ft. steam generating surface | Total lb. steam per hour equivalent |
|---|---|---|---|---|---|---|---|
| **STORAGE SYSTEM** | Pulverizers | | | | Water-tube Boilers | | |
| July, 1932 | 5 | 1 | 4 | 11,250 | 5 | 17,400 | 110,500 |
| July, 1931 | .. | .. | .. | .... | .. | .... | ...... |
| January to July (inclusive, 1932) | 5 | 1 | 4 | 11,250 | 5 | 17,400 | 1,671,000 |
| Equivalent period, 1931 | 7 | 6 | 1 | 220,000 | 3 | 114,577 | 110,500 |
| Total, 1931 | 8 | 7 | 1 | 250,000 | 37 | 126,471 | 1,797,000 |
| **DIRECT FIRED OR UNIT SYSTEM** | Pulverizers | | | | Water-tube Boilers | | |
| July, 1932 | 2 | 2 | .. | 7,000 | 2 | 7,500 | 62,510 |
| July, 1931 | 11 | 8 | 3 | 114,600 | 8 | 117,000 | 1,088,980 |
| January to July (inclusive, 1932) | 42 | 29 | 13 | 214,338 | 38 | 206,586 | 1,930,960 |
| Equivalent period, 1931 | 57 | 41 | 16 | 393,710 | 43 | 363,880 | 4,049,145 |
| Total 1931 | 72 | 52 | 20 | 450,960 | 58 | 417,327 | 4,455,585 |
| | | | | | Fire-tube Boilers | | |
| July, 1932 | .. | .. | .. | ...... | .. | ...... | ...... |
| July, 1931 | 5 | 3 | 2 | 3,900 | 5 | 8,000 | 47,700 |
| January to July (inclusive, 1932) | 12 | 1 | 11 | 12,300 | 12 | 19,000 | 108,750 |
| Equivalent period, 1931 | 24 | 6 | 18 | 26,700 | 24 | 39,954 | 240,000 |
| Total, 1931 | 35 | 11 | 24 | 39,300 | 37 | 59,761 | 347,100 |



One of three Loeffler steam generators installed at the Trebovice station, Czecho-Slovakia. Capacity, 165,000 lb. of steam per hr.

# The Loeffler Super-Pressure Steam Generator

**While considerable information on the Loeffler Steam Generator has already appeared in print, an up-to-date review of the installations made and the operating results obtained with this unique design will undoubtedly be of interest. Mr. Brownlie briefly discusses the principles involved in the design and then proceeds to describe the various installations starting with the original installation in Vienna and concluding with the large units now being installed in Moscow. The latter installation will be the largest high-pressure plant in Europe, each of the two boilers being designed to produce, at maximum rating, 350,000 lb. of steam per hr. at 1900 lb. pressure and 932 fahr. total steam temperature.**

By
DAVID BROWNLIE, LONDON

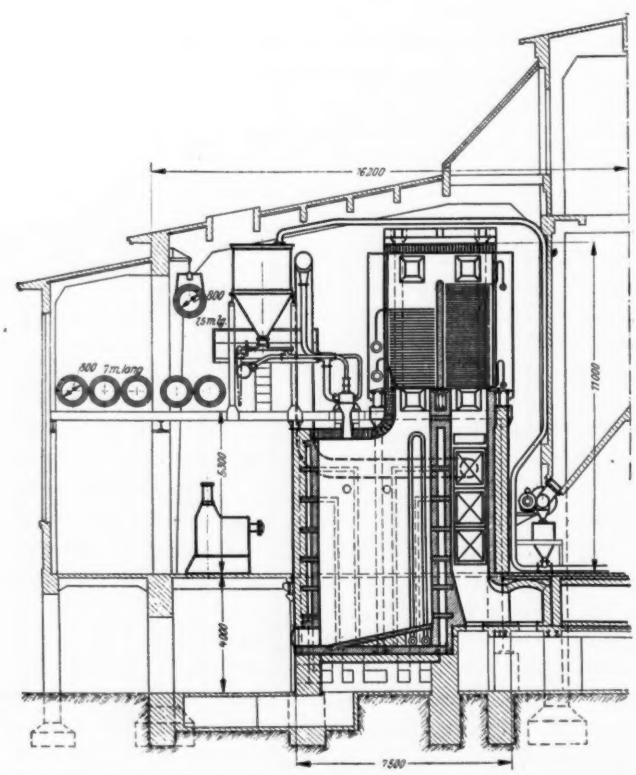
THE use in recent years of very high steam pressures, such as from 1250 to 1900 lb. per sq. in., has resulted in the development of various special designs of steam generating units representing marked variations from the conventional types of water tube boilers which under such conditions have to be constructed with costly, and extremely heavy, forged steel drums. One of the most striking inventions in this field is the "Loeffler" steam generator, developed since 1923 by the late Professor Stephen Loeffler of Vienna, and controlled by the Witkowitzer Bergbau und Eisenhütten Gewerkschaft, Witkowitz, Czecho-Slovakia. The first commercial boiler of 17,630 lb. evaporation per hr. was erected in 1924-1925 at the works of the Wiener Lokomotivfabrik A. G. at Wien-Floridsdorf, Vienna, operating at 1650 to 1800 lb. per sq. in. pressure, with superheated steam at 932 fahr. maximum. Up to this time twelve different Loeffler boilers have been installed and, at present, two very large units of double type, each of 352,640 lb. per hr. maximum evaporation, are under construction for the Thermo-Technical Institute of Moscow (U.S.S.R.).

The basic principle of the Loeffler boiler is to use one or more large evaporator drums or cylinders and heating coils or superheaters of steel tubes, which latter are fixed in a furnace setting and connect to the evaporator drums. Operating pressures vary from 1400 to 1900 lb. per sq. in., but are always over 750 lb. All the steam from the drums passes through the heater coil in the furnace at very high velocity, about 60 to 65 ft. per sec., and is raised to a temperature up to 932 fahr. For this purpose it is necessary to have in the circuit between the evaporator drum and the heater coil a special booster pump which takes all the steam from the drums and forces it through the heater coils at a somewhat higher pressure, say from 1945 to 1975 lb. per sq. in., in the case of 1900 lb. in the drum. Then about 33 per cent of the steam

at 1900 lb. pressure, or other figure, and 932 fahr. is used for driving a steam turbine, and the other 67 per cent passed back to the evaporator drums being "bubbled" through the water below the surface. That is, the steam is generated entirely by passing very highly superheated steam through the water, the evaporator drums being situated at any desired distance from the furnace setting, with suitable pipe connections, and not being exposed to any external heat. The general theory is that narrow-bore steel tubes will stand the action of heat by direct contact with combustion gases, under super-pressure conditions, very much better than large drums. Consequently the evaporator drums can be of much simpler and cheaper design, and need not be of forged construction.

In the Loeffler boiler setting, therefore, all the heat from the furnace, which may be fired in any convenient manner with gaseous, liquid, or solid fuel, is transmitted direct to steam only and not mainly to the water as in ordinary steam generation practice with a small amount for superheating. Further the circulation is entirely positive, because of the use of a separately driven pump, and does not depend upon gravity, while being unaffected by the steam pressure.

The steam heater coils or superheaters are in two stages. The first is a radiant heat superheater lining the combustion chamber walls which raises the steam coming from the evaporator drums at about 600-650 fahr. to 725-740 fahr. From this point the steam passes to the second superheater or re-superheater, of the convection type, where the temperature is raised from 725-740 fahr. to 932 fahr.




**First Loeffler steam generator installed at the Witkowitzer works, Czecho-Slovakia for operation at 1800 lb. pressure and 932 fahr. total steam temperature.**

Standard equipment includes both an economizer and an air heater.

The original boiler at the Wiener Lokomotivfabrik A.G., with a maximum evaporation of 17,630 lb. per hr., is fired generally with low-grade anthracite, the installation including superheaters, feedwater economizer, and air heater. Steam is generated in this case in two parallel evaporator drums, each 23 ft. long and 31.5 in. internal dia., the two drums having been installed to allow of experimental investigations under greatly varying conditions. A steam generation efficiency of over 80 per cent is stated to be obtained, using preheated air at 266 to 320 fahr.

Interesting to note also is that the feedwater economizer is in two stages, the water first being raised in temperature in a heat exchanger by means of condensing low-pressure steam generated from distilled water which circulates through heated cylindrical tubular boilers. This water then enters a pipe coil economizer, where the temperature is raised to 536 fahr. by means of the combustion gases. Further the steam booster pump, of the reciprocating type, and the feed pump are combined in the form of a single, vertical, double crank shaft unit, available for operating under the maximum condition, already mentioned, of 1800 lb. per sq. in. pressure and 932 fahr. superheated steam temperature.

After the satisfactory operation of the first Loeffler boiler at Vienna a unit of 33,060 lb. evaporation per hr. was erected at the Witkowitzer works also operating at 1800 lb. pressure and 932 fahr. superheated steam temperature. Pulverized fuel firing is used, with bituminous coal, the greater part of the air for combustion being preheated to 570 fahr. and mixed with the coal at the burner, with the rest used in the cold condition to convey the pulverized coal from the bunker to the burners. Five evaporator drums are installed, each 23 ft. long and 31.5 in. internal dia., arranged in parallel, this also being partly for experimental reasons since for a small boiler of this size a single drum is sufficient. As with the plant in Vienna, the steam booster pump of the reciprocating type with piston valves is combined with the feedwater pump as a single vertical unit driven by an a.c. motor.

Next the Witkowitzer Company installed two Loeffler boilers, each of 110,200 lb. evaporation per hr., each with two evaporator drums 26 ft. long, and 43 in. internal dia., fixed below the firing floor direct on the foundations, while above the drums is a group of pumps. The whole space occupied is only 59 ft. wide, 50 ft. long, and 53 ft. high, much less than with the ordinary type of super boiler, the maximum pressure being 1900 lb. per sq. in.

At the Witkowitz Works also there is being operated a super-pressure turbine operating normally at 1800 lb. per sq. in., and 932 fahr. superheated steam temperature at the stop valve, giving an output of 18,000 kw., built by the Erste Brunner Maschinenfabrik A.G.

In 1927, a Loeffler boiler of 33,060 lb. per hr. evaporation was installed at the Karolinenschacht

**Loeffler centrifugal steam booster pump at the Karolinenschacht plant at Czecho-Slovakia.**

mine of the Witkowitzer Steinkohlengruben, in Czecho-Slovakia. Shortly afterwards two much larger boilers were installed each of 110,200 lb. per hr. maximum evaporation, while two more boilers, each of 143,260 to 165,300 lb. evaporation, have since been placed in operation. Also three Loeffler boilers, each of 165,300 lb. of water per hour maximum evaporation have now been completed at the Trebovice power station in Czecho-Slovakia.

As regards the general design and construction of the Loeffler boiler the superheater coils are constructed of very resistant molybdenum carbon steel, with 0.6 per cent molybdenum and a tensile strength of 100,000 lb., which is claimed to represent an ample factor of safety at the highest temperatures. For a typical large boiler of 165,300 lb. evaporation, in the case of the radiant heat superheater the outside diameter of the tubes is 2¾ in. with below 1⅞ in. for the internal diameter, the walls being 17/64th in. thick. For the convection superheater or re-superheater the outside diameter of the tubes is 2¾ in., the inside diameter less than 2⅛ in., and the thickness approximately 5/16 in.

Included in the many interesting accessories of the Loeffler boiler are special types of valves and boiler fittings for operating up to 1900 lb. per sq. in. and 932 fahr. superheated steam temperature, and a float type of water level indicator. This works on the electrical principle, with iron core, counterbalanced by the float, so that as the latter rises the weight goes down and vice versa, working in conjunction with a solenoid, altering the amount of current passed in a circuit and giving readings accordingly.

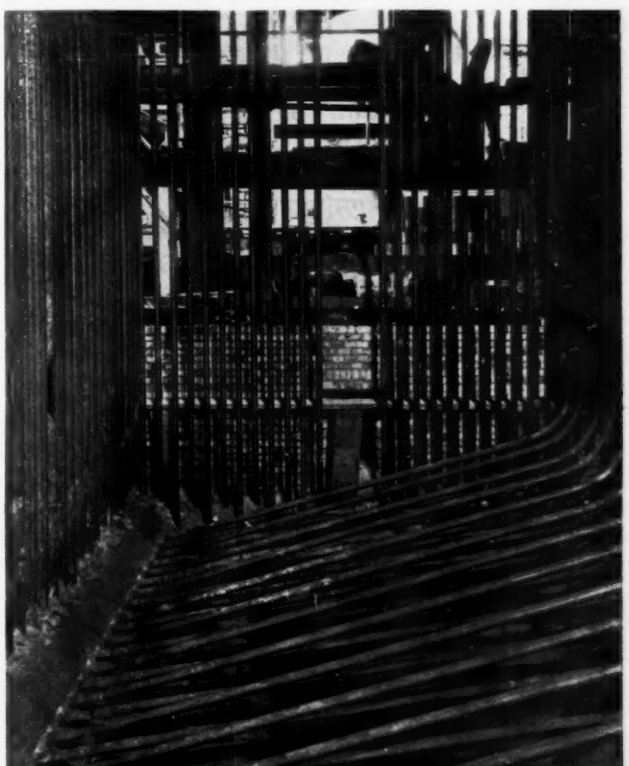
The vital part of the equipment is the booster pump which has to take saturated steam up to 1950 lb. per sq. in. from the evaporating drum, and discharge it under compression through the heater in two stages, so that, as already indicated, the greater part of the highly superheated steam passes back into the evaporating drum, while the remainder goes to the steam turbine.

According to Professor Loeffler there is less trouble in circulating saturated steam with a pump than in circulating high-pressure feedwater, and the problem is stated to be not so difficult as the design and operation of very high pressure compressors, operating up to 15,000 lb., such as are used in the chemical industries.

In the design of this booster pump, the principal objectives have been to provide for the handling of super-pressure steam without breakdown and undue maintenance costs, and to avoid excessive power for driving. Two types of pump are used, depending on the size of the boiler. With an evaporation of 22,040 to 33,060 lb. per hr. or over, the pump is of the centrifugal type, but for smaller units a 3-cylinder vertical reciprocating pump is employed. As previously described pumps of this latter type were used in the original experimental Loeffler boilers and are operating also with considerable success in a number of commercial installations. These include, for example, a boiler with an evaporative capacity of 33,060 lb. per hr., at the Witkowitzer works, and the similar boiler at the power plant of the Karolinenschacht mine.

A valuable field for the Loeffler boiler is the super-pressure locomotive, and in this connection a locomotive constructed in 1930 by the Berliner Maschinenbau A.G. (vormals L. Schwartzkopf) Berlin, is running successfully with a boiler of this type.

Essentially the design of the combined steam booster and feed pump is also of the vertical 3-cylinder type, with the pump cylinder above, and



**View showing radiant superheater of Loeffler steam generator at the Karolinenschacht plant.**

two booster steam cylinders in tandem, having a special design of stuffing box using ring metallic packing of the spring type.

One of the minor difficulties was the piston rings, but this problem has now been solved. These vertical piston pumps are direct driven, with the necessary speed reduction, either by electric motor or steam engine.

With regard to the centrifugal booster pumps for larger duties, that is an evaporation of over about 22,040 lb. per hr., these also have proved to be quite satisfactory, having been designed by Professor Loeffler and constructed by Escher Wyss A.G. of Zürich, as installed in the Witkowitzer plant.

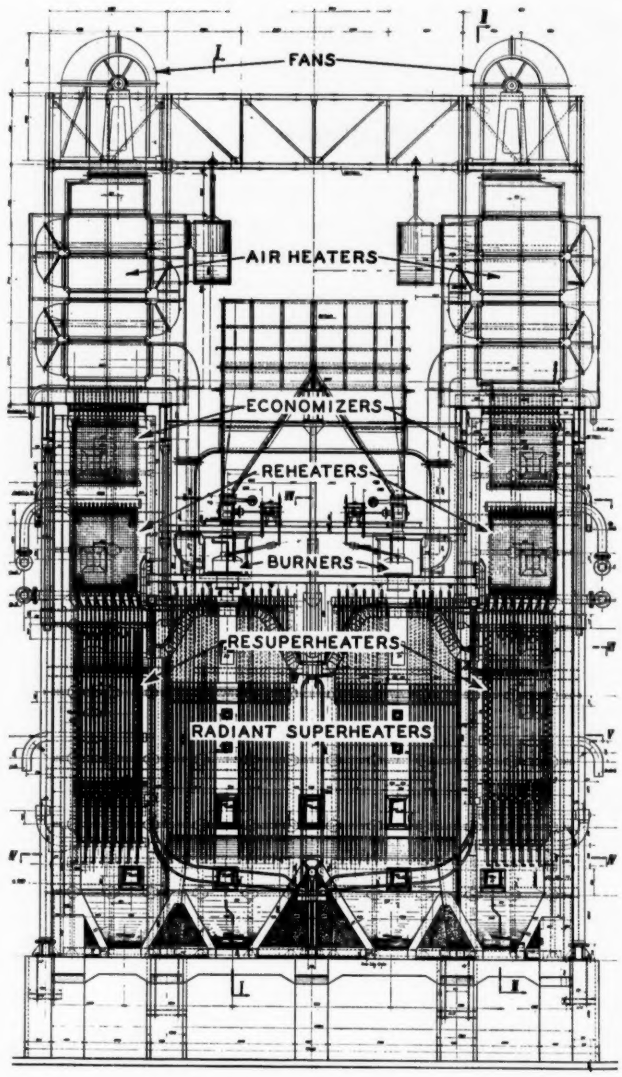
In compressing saturated steam from say 1900 lb. per sq. in. to 1945 to 1975 lb. per sq. in., the main problem was the tightness of the stuffing boxes, and detailed investigations were carried out in connection with the two boilers, each of 110,200 lb. evaporation per hr. at the Karolinenschacht plant. Three methods were studied, the first being the use of a soft packing as in the ordinary centrifugal pump practice for water, which, however, proved to be useless in view of the very high speeds used, 5000 to 8000 r.p.m. Also it was not possible to use the second method investigated, that is labyrinth packing, because of the high pressures involved.

Success was attained however with the third method, the employment of a sealing liquid in the form of a viscous oil. Essentially the bearing is filled with white metal, leaving an annular space for the liquid seal, the oil being circulated at a pressure of about 2250 lb. per sq. in., with a relief valve in the circuit discharging at 1980 lb. per sq. in. For this purpose the pump used in the oil circuit at the Karolinenschacht plant was a runner wheel of 11.8 in., electric driven, forming a 2-chamber gear wheel pump, designed to give a flow of 1321 lb. against a pressure of 2250 lb.

The principle may be described as a form of labyrinth packing in which a small amount of oil escapes in place of steam, generally not more than about 66 to 79 lb. per hr., while the pump shaft, as well as the stuffing boxes, is cooled to prevent undue heating and alteration of the oil viscosity.

Subsequently this oil seal design was modified in conjunction with Escher Wyss & Co., the runner wheel now being on an overhung shaft in a cast steel housing with an outside bearing only, having also an arrangement to reduce the axial thrust, while the stuffing box is provided with a large number of teeth, cut both in the axial and radial directions.

It is stated that this type of oil seal joint is so satisfactory that a pump running at the maximum speed of 8000 r.p.m. loses only about 0.5 per cent of the total amount of steam under conditions of 1950 lb. pressure which steam, however, is not lost being discharged to the turbine. Thus as the result of many months running it is stated the actual steam leakage at 1800 lb. is only approximately 880 lb. per hr., as compared with 1322 lb. guaranteed by the makers, while at lower pressures such as 15 to 30




**Section through two Loeffler generators being installed at Moscow. Evaporation 286,000 to 353,000 lb. of steam per hr. at 1900 lb. pressure and 932 fahr. total steam temperature.**

atm. ~~lb.~~ the leakage is only 176 lb. per hr. Further, it may be mentioned that the steam turbine driving the pump, also of Escher Wyss make, allows of very easy regulation within a wide range of 2000 to 8000 r.p.m. to enable the boiler to run at extremely low load.

Interesting also in this connection is the discovery made at Witkowitz that highly superheated steam at 752 fahr. taken from the radiant superheater to drive the pump means that deterioration from erosion due to the use of wet saturated steam is avoided.

With regard to the plant the Witkowitzer Bergbau und Eisenhütten Gewerkschaft now have in hand for Moscow, this consists of two complete Loeffler boilers, representing the latest principles of design, each of which will have a normal duty of 286,520 lb. of water per hr., with an overload duty of 352,640 lb. operating at 1900 lb. per sq. in. pressure and 932 fahr. superheated steam temperature. These will be the largest boilers in Europe operating under super-pressure conditions and apparently are to be installed at one of the power stations in Moscow. They are designed for pulverized fuel

firing, and will use low-grade coal from the Donetz area.

The boilers are set as shown in the accompanying drawing, the common combustion chamber having a total volume of 21,180 cu. ft., and having two rows of eight pulverized fuel burners. The air for combustion is preheated to 485 fahr.

The induced draft fans are of the double suction type, having a maximum duty of 140,140 cu. ft. of flue gases per min. at a temperature of 410 fahr. discharging through dust separators, of a type not specified, to the chimney. The convection type re-superheaters are each of 10,760 sq. ft. heating surface, with 48 coils, 2.75 in. outside dia., and are designed to raise the steam from 735 fahr., as received from the radiant heat superheaters of 3120 sq. ft. heating surface, to 932 fahr.,—discharging about 33 per cent of the steam at the latter temperature to the turbine and the remaining 67 per cent to the evaporator drums of the boilers.

The reheaters receive steam at 380 lb. pressure and 535 fahr. and raise it to a temperature of 752 fahr. Each reheater has 6886 sq. ft., of heating surface consisting of 32 coils 1.87 in. external dia.

The feedwater economizers have 6080 sq. ft. of heating surface each, taking water at 410 fahr. after bleeder heating. The air heaters are of the "Thermorex" type, constructed by the Witkowitzer Company.

Each boiler has five evaporator drums 26 ft. long and 43 in. dia., and also one mud drum 6 ft. 6 in. long and 43 in. dia. A single-stage, turbine-driven, centrifugal steam booster pump having a maximum duty of 1,100,000 lb. of saturated steam per hr. is provided for each unit.

It is claimed that there will be no difficulty in constructing and operating much larger Loeffler boilers and plans have been made for units of 551,-000 lb. per hr. evaporation.

The main claims for the Loeffler boiler include low capital and maintenance costs, very high efficiency, uniform superheated steam temperature within fine limits, clean and dry steam, and flexibility in design, construction and operation of the plant. Also it is not necessary to use special steel, heavy supporting structures, expanded joints, make-up feedwater plant, or steam accumulators.

As already indicated a simple type of evaporator drum, internally heated only, is much cheaper for conditions of 750 to 1900 lb. per sq. in. pressure as compared with forged steel drums. The weight is less, which means elimination of heavy supporting structures and large foundations, while the drums can be in any convenient position in regard to the steam heating coils. Impure or dirty feedwater makes no difference since the water is not exposed to external heat, and scale and deposits in the evaporator drum do not affect the metal. Consequently make-up softening plant can be eliminated.

Also the steam is dry and clean because it is given off relatively slowly from a wide area of water in the large evaporator drums, while the centrifugal action of the steam booster pump used for the larger plants tends to separate moisture and solid impurities. Further, an increase in steam pressure causes no difficulties in the way of burning and deterioration of the boiler tubes due to an insufficient rate of heat transmission, even with distilled water, since the circulation is dependent upon a mechanically driven pump.

It is claimed the heater coils, like the steam booster pump, do not in practice give rise to trouble under the conditions of a steam velocity of about 65 ft. per sec. For example, in the case of the Vienna and the Witkowitz plants, pieces cut out of the heater coils after 3000 hr. running showed no deterioration of the metal, while the tubes are quite clean inside since only relatively dry and clean steam is heated. Also the boiler is extremely flexible and can be started up very rapidly from cold using low pressure auxiliary steam. Under conditions of say from 165 to 225 lb. per sq. in. the time is about 2 to 3 hr. for the average size installation and much less of course if the given boiler is in circuit with other Loeffler boilers running at full pressure.

With regard to the disadvantage of the equivalent of 2 per cent of the total steam generated used for the steam booster pump it is contended this is a relatively minor matter in view of the net advantages obtained.

I have to express my best thanks to the Witkowitzer Bergbau und Eisenhütten Gewerkschaft and also to the Continental Steel Trading Co. Ltd., of London, their representatives in Great Britain, for full information, including all the photographs and line drawings reproduced.

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**The Davis Engineering Corporation,** 90 West Street, New York, N. Y., as part of their sales expansion plan, has appointed Fred W. Carlson, 959 Harrison St., Seattle, Wash., representative in that territory.

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**The General Refractories Company,** Philadelphia, Pa., announces that an arrangement has been concluded with the McLeod & Henry Company of Troy, N. Y., whereby they are now in a position to offer to the trade the well-known and high quality CARBEX (Silicon Carbide) commodities manufactured by the McLeod & Henry Company.

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**Alex Dow,** past president of the American Society of Mechanical Engineers, has been appointed chief of the Detroit Ordinance District.

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**Calvin W. Rice,** secretary of The American Society of Mechanical Engineers, has been appointed a member of the National Research Council on the Division of Engineering and Industrial Research.

# Comparison of A. S. M. E. Fusion Welding Requirements for Unfired Pressure Vessels

This tabulation, contributed by L. G. Haller of the Hedges-Walsh-Weidner Company, Chattanooga, Tenn., shows the main differences between Class 1 and Class 2 workmanship. The A.S.M.E. Boiler Code for fusion welding is the same as the Class 1 code for unfired pressure vessels except that the boiler code requires that all seams be X-rayed. The main difference between Class 1 and Class 2 welding, aside from the annealing and X-raying, is that Class 1 work is continuously checked on every job by physical tests made of coupons attached to each vessel, while Class 2 work is checked only once every six months by requiring the welders to make only one test coupon semi-annually.

| | CLASS 1 | CLASS 2 |
|---|---|---|
| X-RAY TEST TO PROVE SOUNDNESS OF WELDS: | All longitudinal seams and one circular seam. | None required. |
| ANNEALED TO RELIEVE STRESSES: | Yes. | Only in rare instances. |
| PLATE THICKNESS: | Unlimited. | 1½" Maximum. |
| ALLOWED EFFICIENCY OF WELD: | 90% of solid plate. | 80% of solid plate. |
| QUALIFICATIONS OF WELDERS: See Text Above Table. | Class 1 welders required. 2 Coupons attached to shell plate being welded, one on each end of one longitudinal joint of each vessel. CONTINUOUS CHECK. | Class 2 welders required. Welder qualified by making only one coupon every six months. CHECK ONLY AT 6-MONTH INTERVALS. |
| BEND TEST: | 30%. | Electric—20%. Oxyacetylene—15%. |
| TENSILE TEST OF JOINT: | At least equal to the minimum of the range of plate on one coupon taken from every vessel. | Equal to 95% of minimum range of plate on one test coupon only, made once each 6 months. |
| ALL WELD METAL TEST: | 20% Elongation in 2". | None required. |
| WELD METAL DENSITY TEST ON SPECIFIC GRAVITY: | Specific gravity 7.80 Min. | None required. |
| ALL WELD METAL TENSILE TEST FOR PLATES ⅝" AND HEAVIER: | Equal to plate. | None required. |
| PURPOSES FOR WHICH VESSELS MADE ACCORDING TO SPECIFIED CLASS MAY BE USED: | Class 1 can be used on all classes of pressure vessels. | Class 2 can be used on all vessels excepting those containing lethal gases or lethal liquids and/or those containing liquids operating at a temperature of 300° F. or above. The maximum pressure at which any vessel in this class may be operated is 400 lb. per sq. in., and/or the maximum temperature is 700° F. and the plate thickness as required by the permissible stress allowance shall not exceed 1½". This pressure limitation does not apply to vessels operated under hydraulic pressure at atmospheric pressure. |

NOTE: The above is only a synopsis of the requirements of Class 1 and Class 2 Fusion Welding. For full details see the 1931 issue of A. S. M. E. Code for Unfired Pressure Vessels, which can be secured from the American Society of Mechanical Engineers, 29 West 39th St., New York City.

# REVIEW OF NEW TECHNICAL BOOKS

**Any of the books reviewed on this page may be secured from In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York**

## Thermodynamics
**(Third Edition)**

**By J. E. Emswiler**

THE first edition of this book, published in 1921, was intended to present the subject matter with especial regard to the student's viewpoint. The ready acceptance of the text by teachers in engineering colleges all over the country testified to the success of the author's efforts.

In this new edition, the third, a considerable part of the text has been rewritten, much new material introduced, and several new problems added at the ends of the chapters.

The more important additions are as follows: two tables of the properties of ammonia; a fairly extensive treatment of the principle of the absorption system of refrigeration and, in this connection, an introduction to the idea of the use of solutions in power cycles; a summary of the rather numerous forms of the gas equations, and the solution of several problems exemplifying their use; an extension of the chapter on mixtures, consisting of articles on evaporation vs. boiling, on the approximate derivation of Carrier's equation, and on the theory of the wet-bulb thermometer, with some further illustrative examples; in the chapter on the air heat engine, articles dealing with the gas turbine, with throttling of the Otto cycle engine, and with supercharging; and finally, a rather extensive article on supersaturation of steam.

With the appearance of the new steam tables by Professor Keenan, the opportunity has been taken to change all references to the new tables and to use numerical quantities from them.

This book contains 347 pages, size 6 x 9. Price $3.00.

## Industrial Gas Series—Combustion
**(Third Edition)**

ALTHOUGH a third edition, this book, prepared under the supervision of the Committee on "Combustion" of the Industrial Gas Section of the American Gas Association, has been so completely revised both with respect to content and treatment that it is in reality a new book.

In the eight-year interval between the first edition and this, much development has taken place in the industrial gas field both in practice and in knowledge of fundamental theory. The market for gas as a fuel has broadened to such an extent that its competitive influence has become manifest. From time to time articles appear in technical journals discussing the competitive aspects of fuels for industrial heating and advocating the use of this or that fuel and equipment. A substantial portion of this book deals with these points, and shows the methods by which fuel consumption and fuel costs can be calculated.

The following chapter headings give a good idea of the scope covered by this book: Heat and Its Measurement; Gas Volume and Pressure; Chemistry of Combustion; Thermal Capacity; Heat Transfer; Combustion Data of Commercial Gases; Atmospheric Burners; Industrial Combustion Equipment; Temperature Control; Heat Salvage Methods; Gas Analysis; Fuel Comparisons. Each chapter is followed by a comprehensive bibliography of books and articles pertaining to the subject of that chapter.

The book contains 208 pages, size 9 x 12. Price $2.00.

## A. S. T. M.
## Refractories Manual

THIS publication, issued by the American Society for Testing Materials, brings together in convenient form the several A. S. T. M. standard specifications, methods of testing and definitions pertaining to refractories. It also includes the latest revision of the Manual for Interpretation of Refractory Test Data.

The contents include standard specifications for clay fire brick for malleable furnaces, stationary boiler service and marine boiler service. Methods of testing are given for refractory brick, for refractory materials under load at high temperatures, for porosity and permanent volume changes in refractory materials, for softening point of fire-clay brick, and for chemical analysis of refractory materials, including chrome ores and chrome brick. Also included are tentative test methods for the resistance of fire-clay brick to thermal spalling action and for determining the particle size of ground refractory materials. Standard definitions include clay refractories and terms relating to refractories and to heat transmission of refractories.

The Manual for Interpretation of Refractory Test Data was prepared by Committee C-8 on Refractories. It is felt that the desired effectiveness in the use of refractory tests in the control of manufacture, inspection and utilization of refractories cannot be attained until test procedures and methods of reporting data are on a sound statistical basis. The Manual is an important step in this direction.

The *Refractories Manual* comprises 93 pages, size 6x9. Price 50 cents.

# NEW CATALOGS AND BULLETINS

**Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine**

### Continuous Blow-Off Equipment

Bulletin No. 692 describes the new automatic continuous blow-down system developed by the Cochrane Corporation. In this system the blow-off water is discharged into a flash tank having suitable baffles for purifying the flashed steam. Where required some of this steam may be recovered at relatively high pressure. Otherwise the flashed steam may be condensed in heating the feedwater, either by direct admission to the exhaust heater or in a flash condenser. 8 pages, 8½ x 11—The Cochrane Corporation, 17th Street and Allegheny Avenue, Philadelphia, Pennsylvania.

### Flow Meters

Bulletin No. 690 has recently been issued describing the Cochrane High Torque Flow Meters. The main feature of this meter is the high torque design. This bulletin is very comprehensive and includes charts, tables and photographic reproductions of actual installations. 32 pages, 8½ x 11—Cochrane Corporation, Philadelphia, Pa.

### Gas Burners

A catalog entitled "Hy-Power Radiant Cross Low Pressure Gas Burners" has been issued by The Sonner Burner Company. The design and construction of these boilers are described in detail. The application of these burners to the various types of boilers is shown. Charts, tables and sketches are included. 32 pages and cover, 8½ x 11—The Sonner Burner Company, Winfield, Kansas.

### Handling Materials by Air

A new catalog has recently been issued entitled "Handling Materials By Air" describing the Raymond System for Mechanical Air Separation, Vacuum Air Separation, Air Drying, Air Conveying and Dust Collecting. The catalog is profusely illustrated and also includes sketches and a table of sizes and specifications of Raymond Mechanical Air Separators. 16 pages and cover, 8½ x 11—Raymond Bros. Impact Pulverizer Company, 1315 North Branch Street, Chicago, Illinois.

### Heat Resisting Paints

A new pamphlet has just been issued describing Ce-Co Hi-Degree Gray Coating for temperatures ranging from 600 to 1400 deg. fahr. This Coating is a scientifically designed product which not only withstands high temperatures but also prevents rust even when subjected to weather exposure and fumes from plant or refinery operations. The specifications for use are set forth. Numerous prominent plants in which Ce-Co Hi-Degree Gray Coating has been applied are illustrated. 4 pages, 8½ x 11—Cheesman-Elliot Company, 639 Kent Avenue, Brooklyn, New York.

### Industrial Rubber Goods

A condensed catalog entitled "Engineering Data, Industrial Rubber Goods" describes the comprehensive line-up of principal industrial rubber goods manufactured by The B. F. Goodrich Rubber Company. On page 3, table No. 1 on rubber transmission belting, gives the horsepower capacities, minimum pulley diameters, leather belt equivalents and list prices on all commonly used sizes of transmission belts. Tables No. 3 and No. 6 give data which it is claimed have never been published in the same form. 24 pages and cover, 8½ x 11—B. F. Goodrich Rubber Company, Akron, Ohio.

### Pressure Controller

A new bulletin No. 70 has been issued describing the Fisher Wizard Pilot Pressure Controller. These controllers have been designed to control reduced pressures, relief or back pressures, for boiler pressure control by regulating the gas or oil fuel supply, for steam, water, gas, oil, air and other fluids. The design and construction of this controller are set forth and a table of prices and standard valve bodies are included. 8 pages, 8½ x 11—Fisher Governor Company, Marshalltown, Iowa.

### Pumps

A pamphlet has just been issued describing the new Ingersoll-Rand pumping unit comprising an Ingersoll-Rand Pump and a General Electric Motor. The unit is shipped completely assembled and is supplied in capacities ranging from 5 to 800 gal. per min. and ¼ to 25 hp. The unit is built with an open type, totally enclosed or explosion-proof motors. Photographs of the pumping unit installed in various industries are reproduced. 4 pages, 8½ x 11—Ingersoll-Rand, 11 Broadway, New York.

### Rotary Pumps

Bulletin PX4 entitled "Northern Rotary Pumps" describes the construction and application of these pumps. The range of capacities is from 6 to 42 gal. per min. and is capable of pressures up to 1000 lb. on lubricating oil. These pumps may be used for fuel oil, kerosene, gasoline and lubricating oil. 4 pages, 8½ x 11—Northern Pump Company, Minneapolis, Minnesota.

### Screw Pumps

Bulletin No. 145 describes the construction and design of the Morris Screw Pumps. These pumps are particularly applicable for services such as drainage, condenser circulation, etc., where large quantities of water are to be delivered at comparatively low and moderate heads. This bulletin includes curves, tables of performance and various sketches. 8 pages, 8½ x 11—Morris Machine Works, Baldwinsville, New York.

### Small Portable Recording Thermometer

Bulletin No. 1040 describes the features, design and construction of the new Tag Miniature-Size Recording Thermometer and the new Tag Square-Case Dial-Indicating Thermometer. These instruments have been developed to check the performance of refrigerating, air-conditioning and heating equipment. Prices and specifications are set forth. 4 pages, 8½ x 11—C. J. Tagliabue Mfg. Company, Park and Nostrand Avenues, Brooklyn, New York.

### Speed Reducers

Bulletin No. 55 entitled "Jones Spur-Gear Speed Reducer Unit" sets forth briefly the general construction features and the method of rating applied to the unit. Drawings and tables giving the various dimensions, reductions and capacities are included. Photographic reproductions show various applications of the unit. 16 pages, 8½ x 11—W. A. Jones Foundry and Machine Company, 4401 Roosevelt Road, Chicago, Illinois.

### Wire Cloth

Catalog No. 32 describes the Woven Wire Screens, Metallic Filter Cloth, End-Shāk Testing Sieve Shaker, Testing Sieves and Foundry Riddles. It contains a glossary of wire cloth terms and a discussion of the method of testing wire cloth. Tables and list prices of the various products are also included. 104 pages and cover, 4½ x 7⅛—Newark Wire Cloth Company, Newark, New Jersey.

## NOTICE

**Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to**

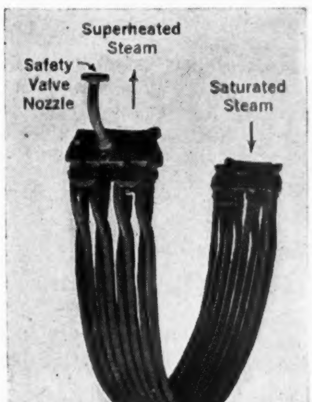
**COMBUSTION**
**200 Madison Ave., New York**

# NEW EQUIPMENT

## of interest to steam plant Engineers

### New Superheater for h.r.t. Boilers

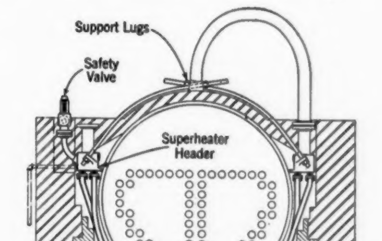
A new and improved superheater was recently developed by The Superheater Company, 60 East 42nd Street, New York City. Unique in design, this superheater is of compact and simple construction and can be installed by any




regular plant attendant. The superheater is standard for all h.rt. boilers.

This h.r.t. superheater comprises two cast-steel headers, suspended one on each side of the boiler shell and connected by detachable tubular elements or units extending around the underside of the boiler. The headers are supported by adjustable clamped steel rods. By raising or lowering the headers, the units are correspondingly raised or lowered in the combustion chamber and thus the desired degree of superheat or final temperature of the steam is obtained.

This superheater is automatic in operation. Saturated steam is carried



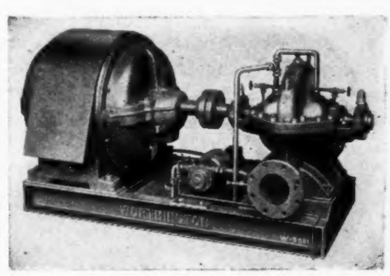

from the boiler nozzle through a connecting pipe to one header, known as the saturated-steam header. From there it passes to the other header or superheated-steam header, through the units under the boiler, during which it is subjected to the relatively intense heat of the gases of combustion in the combustion chamber. The steam, then superheated, passes to the main steam line for use in the plant.

Further information may be obtained by writing to The Superheater Company for bulletin T-22 which describes and illustrates this equipment.

### New Automatically Primed Centrifugal Pumping Unit

Worthington Pump and Machinery Corporation, Harrison, New Jersey have recently placed on the market a new self-contained automatically primed centrifugal pumping unit, having many features.

The new unit comprises an electrically-driven ball bearing centrifugal pump, mounted with its motor, on a fabricated steel bedplate, together with a Monobloc priming unit of the wet vacuum type, controlled by an electric pressure switch. The priming pump or evacuator, is an adaption of the 'Hytor' pump, and is licensed to Worthington under patents of the Nash Engineering Company.



The evacuator is connected to the "high spot" of the suction volute by means of substantial tubing, and is sealed with clear water held in a reservoir built into the bedplate of the complete unit. The evacuator operates to remove air from the centrifugal pump, thereby causing it to be primed.

The evacuator motor is connected across the main pump motor line at a point between the starting switch and the motor, so that in starting the motor the evacuator motor also starts. The pressure switch is placed in the evacuator motor circuit and its pressure connection is piped to the discharge nozzle of the main pump. Whenever the discharge pressure of the main pump is below a pre-determined point the pressure switch is held in the closed position. When the discharge pressure comes up to normal the switch opens and remains open as long as the pressure is maintained. If the pump loses its prime the discharge pressure naturally drops. The pressure switch is thereby closed causing the evacuator to operate until the pressure is again built up to normal. A check valve in the evacuator suction line prevents air leakage from the evacuator to the main pump when the evacuator is not in operation.

As the evacuator motor is in operation only when starting the unit or when it is necessary to reprime the main pump, no more power is used than with a non-priming unit. Likewise as the priming unit is mounted on the bedplate between the main motor and the centrifugal pump, no more floor space or head room is required than with a non-priming unit.

The advantages claimed for this unit are: the use of a modern, high efficiency, ball-bearing centrifugal pump; no compromise necessary on the size and type of pump for a particular service; a priming unit that operates only when needed; the use of no more power and no more space than a non-priming unit.

### Small Stoker Unit

Combustion Engineering Corporation, 200 Madison Avenue, New York, has recently placed on the market a new underfeed stoker suitable for application to both heating and industrial boilers in the approximate range of 40 to 150 developed boiler horsepower. This stoker is heavily built throughout and embodies a number of distinctive features. Its fuel-feeding mechanism is of the ram or plunger type and comprises a main ram or pusher and auxiliary pushers, all mounted on a sliding plate which moves back and forth in the bottom of the retort. The grate surface is composed of stationary bars with moving elements or tuyeres which serve to agitate the fuel bed and make for more effective air distribution. Standard equipment includes dead plates on either side of the active grate surface, but at the option of the purchaser these may be replaced by easily operated shaking dump grates of sectional type.

The drive is supplied by a constant speed motor, variation in fuel supply being secured by means of a special timing device which regulates the number of strokes of the plunger per minute in accordance with load requirements. An eight to one speed range is thus secured. The transmission is very rugged and is equipped with roller bearings. The fan is integral with the drive and is equipped with silent inlet dampers.

The control system, included as standard equipment, provides continuous adjustment of fuel feed and air supply over a wide range of load, and automatic on-and-off control during banking periods.

This stoker is identical in principle to the Company's Type E Stoker which has been on the market for nearly 30 years, and which is serving over 11,000,-

000 sq. ft. of boiler heating surface in this country.

A folder describing this stoker is available and will be sent upon request.

# BOOKS for the Engineer

## 1—American Machinists' Handbook (Fifth Edition)

By Fred H. Colvin and Frank A. Stanley

1140 Pages 4 x 7 Price $4.00

Every section of the Fifth Edition of this well-known manual has been thoroughly revised—some of them have been practically entirely re-written. A great deal of the new material is in the shape of data and methods which have been developed and are now being used in some of the world's leading manufacturing concerns. Another feature is in the insertion of special tables and diagrams to help in estimating and selecting proper equipment for various jobs. Obsolete material has been weeded out, making the book 100 per cent usable and up-to-date.

## 2—Pulverized Fuel Firing

By Sydney H. North

204 Pages illustrated Price $2.25

The author of this book, an Englishman, briefly reviews the history of pulverized fuel as a prelude to a discussion of its development to the present day. Contemporary designs of furnaces, burners, feeders, pulverizing mills, driers, dust collectors, etc., are described and illustrated, as are actual installations in America and Europe which exemplify the trends of practice. Chapters are devoted to the combustion of pulverized fuel and its use in connection with Lancashire boilers, marine boilers and in metallurgical furnaces.

## 3—Handbook of the National District Heating Association—1932 (Second Edition)

538 Pages 6 x 9 Price $5.00

This handbook, which is essentially an encyclopedia of district heating, will be of interest and value not only to those who are actively engaged in this work but also to those who desire to familiarize themselves with this important industry.

The opening chapter tells of the growth of this industry from its beginning in 1877 up to the present. Other chapters present engineering data useful in the calculation of heating requirements, planning and designing of heating plants and systems. The final chapters discuss rates and sales activities of the district heating industry, and the economical use of steam. This latter chapter is probably one of the most interesting and valuable chapters of the book as it gives much detailed information covering the possibilities of reducing waste in steam.

## 4—BEHEMOTH: The Story of Power

By Eric Hodgins and F. Alexander Magoun

354 Pages 6½ x 9 Price $3.50

Setting out to prove no theses and taking no sides in the quarrels centering around our machine civilization, Eric Hodgins and F. Alexander Magoun have told in BEHEMOTH: The Story of Power, the first complete story of this age of power and of its creation out of the vague and confused beginnings that followed the close of the Middle Ages. Combining vivid history and biography with sound science, Mr. Hodgins and Mr. Magoun paint a picture of the rise of power from primitive days, when muscles were the only power machines, down to the modern marvels of machinery, which cram 100,000 horsepower into the size of a modern five-room apartment. BEHEMOTH is the story of an age, entertainingly told in terms of the men who created it.

## 5—Power Plant Management

By Walter N. Polakov

171 Pages Price $2.00

This book offers information of considerable value to those concerned with the management or supervision of power plants, and will help to solve many problems.

Today, power plant cost comes next to payroll as an expense item in textile finishing, paper products, food industries and other enterprises. If the application of efficient methods—checking layouts, costs, waste, etc.—in the generation, distribution and utilization of power, and especially in the scientific organization of the human element, savings of tens and hundreds of thousands of dollars are possible. It is to show management's place in creating these savings—to outline the simple proceedings necessary for the typical power plant, large or small—that this book was planned.

## 6—General Engineering Handbook (First Edition)

Editor-in-Chief:
Charles Edward O'Rourke

922 Pages Price $4.00

The plan for this handbook, according to the editor-in-chief, who is Assistant Professor of Structural Engineering at Cornell University, was conceived in the belief that a great amount of fundamental engineering data could be assembled in a compact pocketbook of not over 900 pages, which would be valuable as a ready reference and hand companion for practicing engineers and for students. The purpose is to supply a compact reference work of important fundamentals for all engineers.

The author seems to have accomplished this in a most satisfactory manner. There are 31 sections, each section dealing with one general subject. Six of these sections contain material which is of importance to all engineers; others belong in the fields of civil, mechanical, electrical engineering, etc. Also engineering mathematics.

The book contains tables and charts useful in the various branches of engineering. An important factor is a bibliography of the important works dealing with the subject, at the end of each chapter. There is also a comprehensive index.

**IN-CE-CO PUBLISHING CORPORATION, 200 Madison Avenue, New York, N. Y.**

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